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(54) **AUTOMATED IDENTIFICATION AND ASSEMBLY OF SHOE PARTS**

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See application file for complete search history.

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(57) **ABSTRACT**

Manufacturing and assembly of a shoe or a portion of a shoe is enhanced by automated placement and assembly of shoe parts. For example, a part-recognition system analyzes an image of a shoe part to identify the part and determine a location of the part. Once the part is identified and located, the part can be manipulated by an automated manufacturing tool.

19 Claims, 24 Drawing Sheets
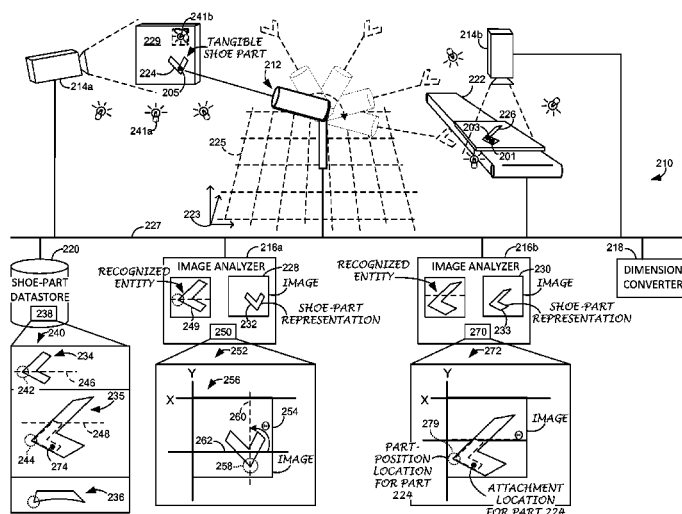
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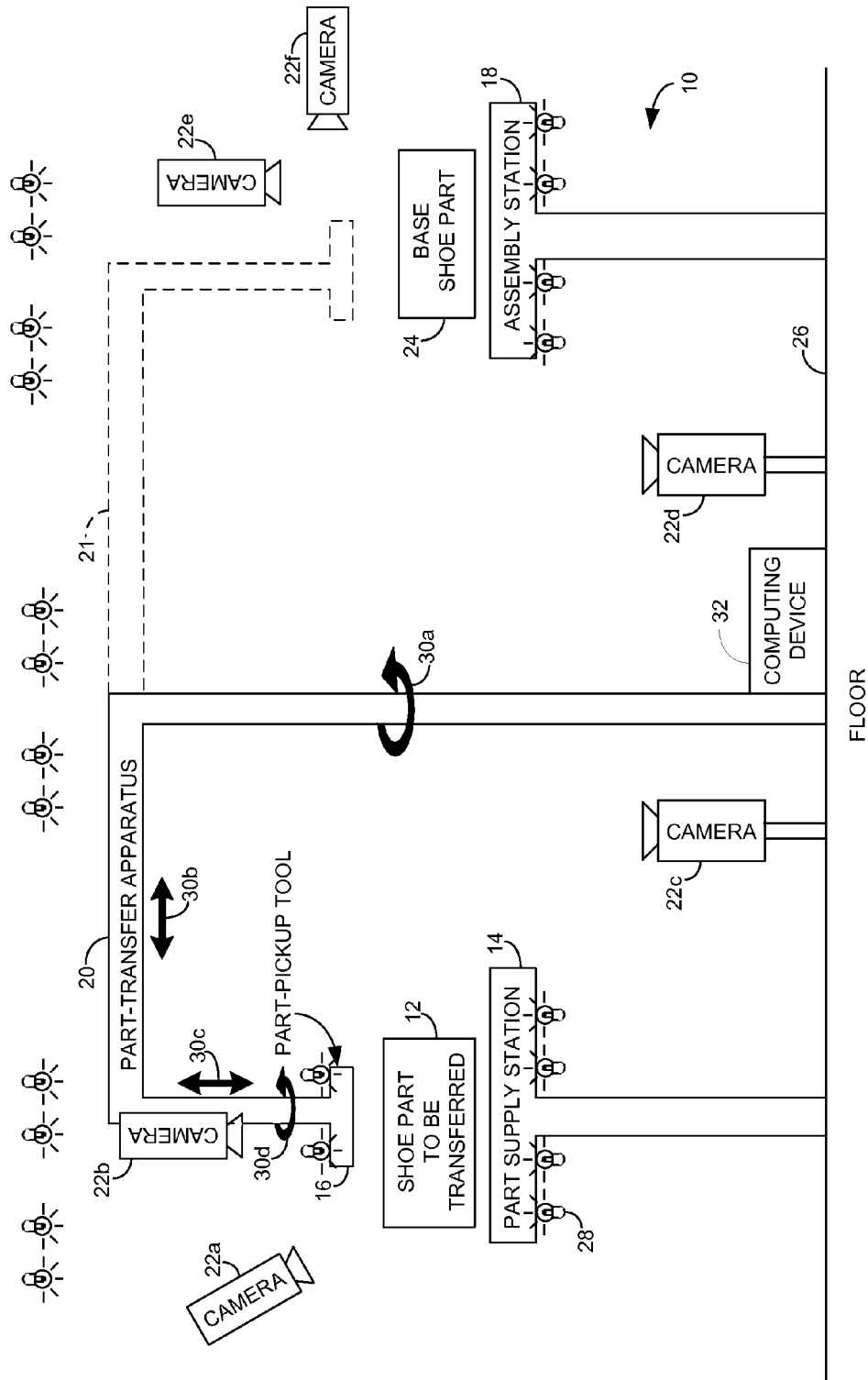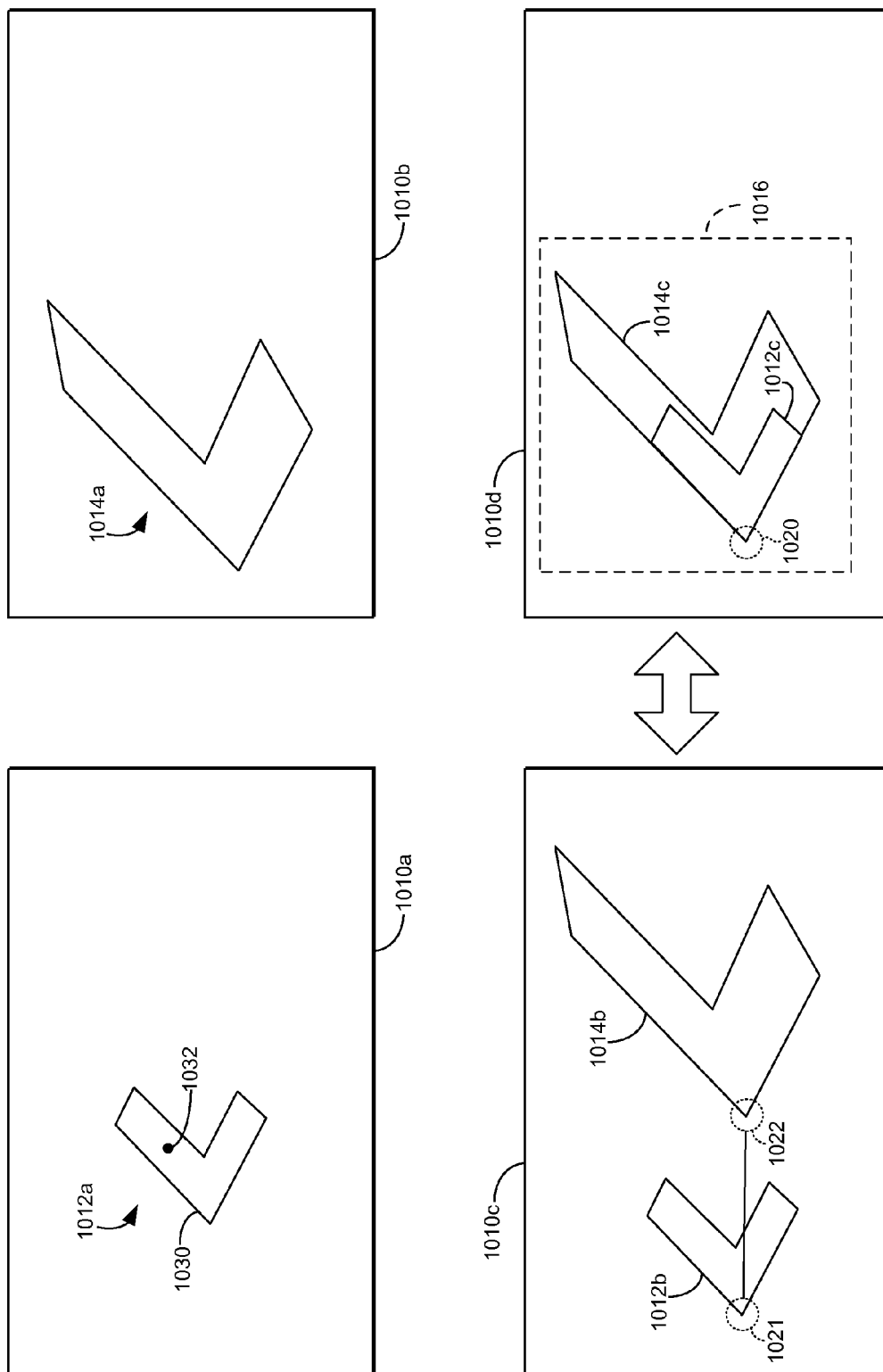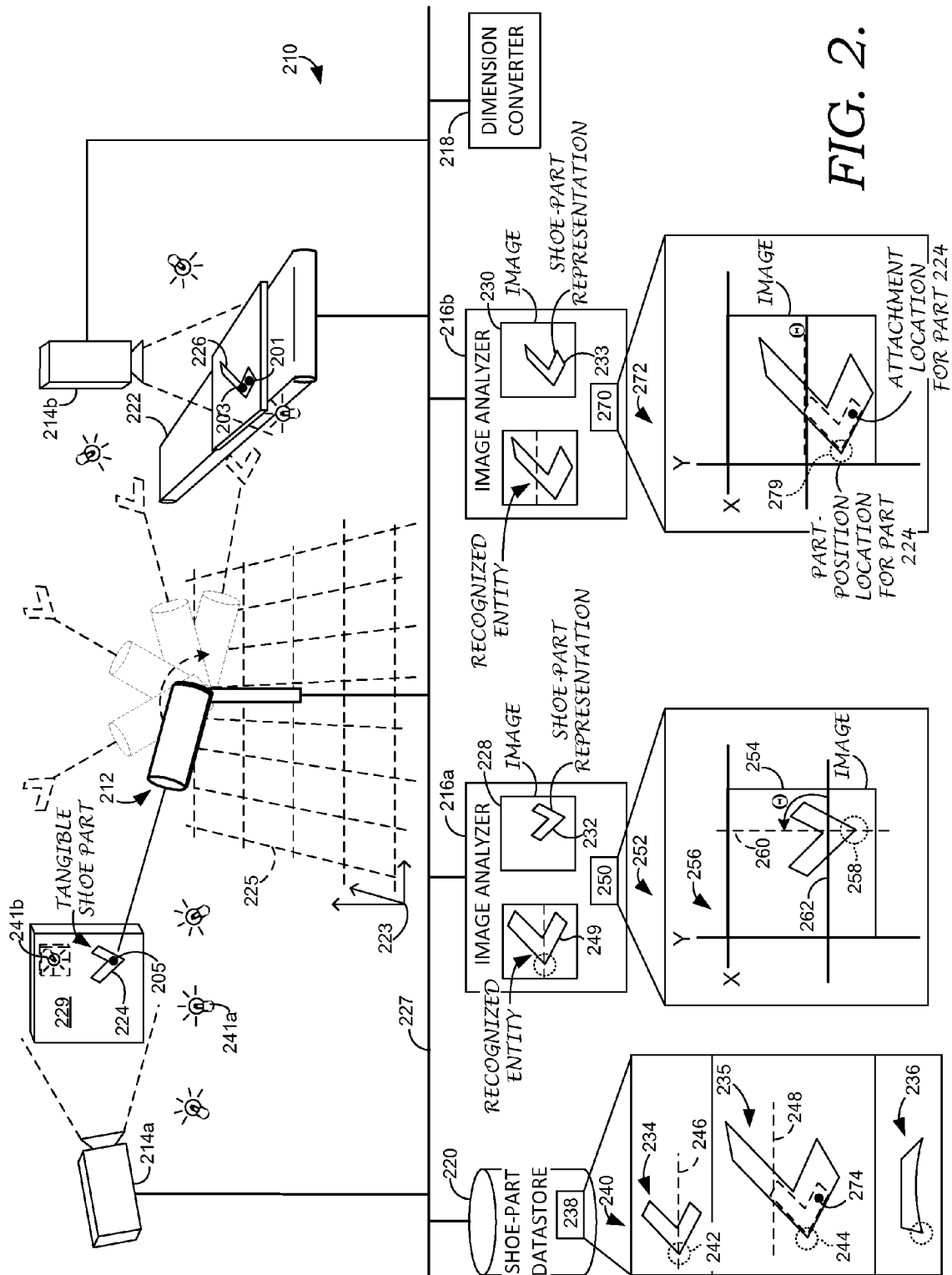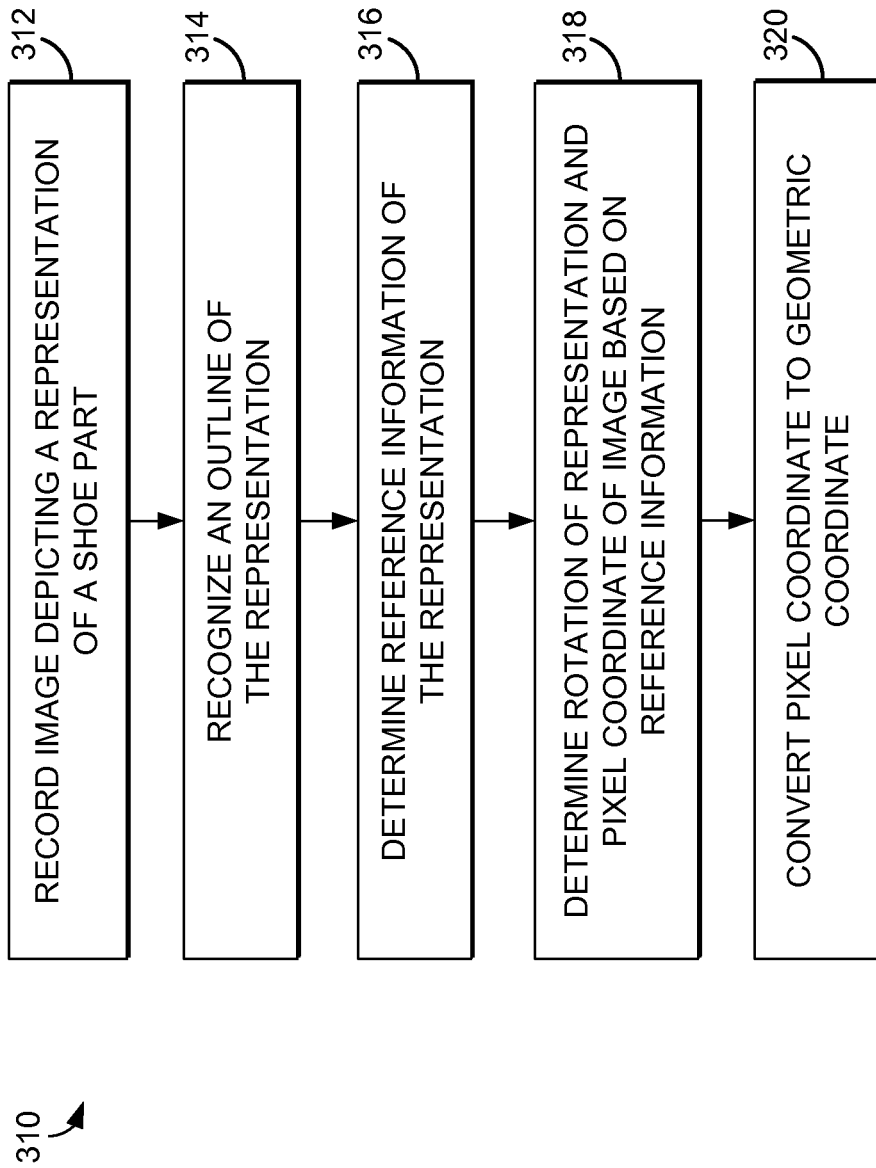
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FIG. 1A.

FIG. 1B.

FIG. 2.

310

312 — RECORD IMAGE DEPICTING A REPRESENTATION OF A SHOE PART

314 — RECOGNIZE AN OUTLINE OF THE REPRESENTATION

316 — DETERMINE REFERENCE INFORMATION OF THE REPRESENTATION

318 — DETERMINE ROTATION OF REPRESENTATION AND PIXEL COORDINATE OF IMAGE BASED ON REFERENCE INFORMATION

320 — CONVERT PIXEL COORDINATE TO GEOMETRIC COORDINATE

FIG. 3.

FIG. 4.

FIG. 5.

FIG. 6.

712

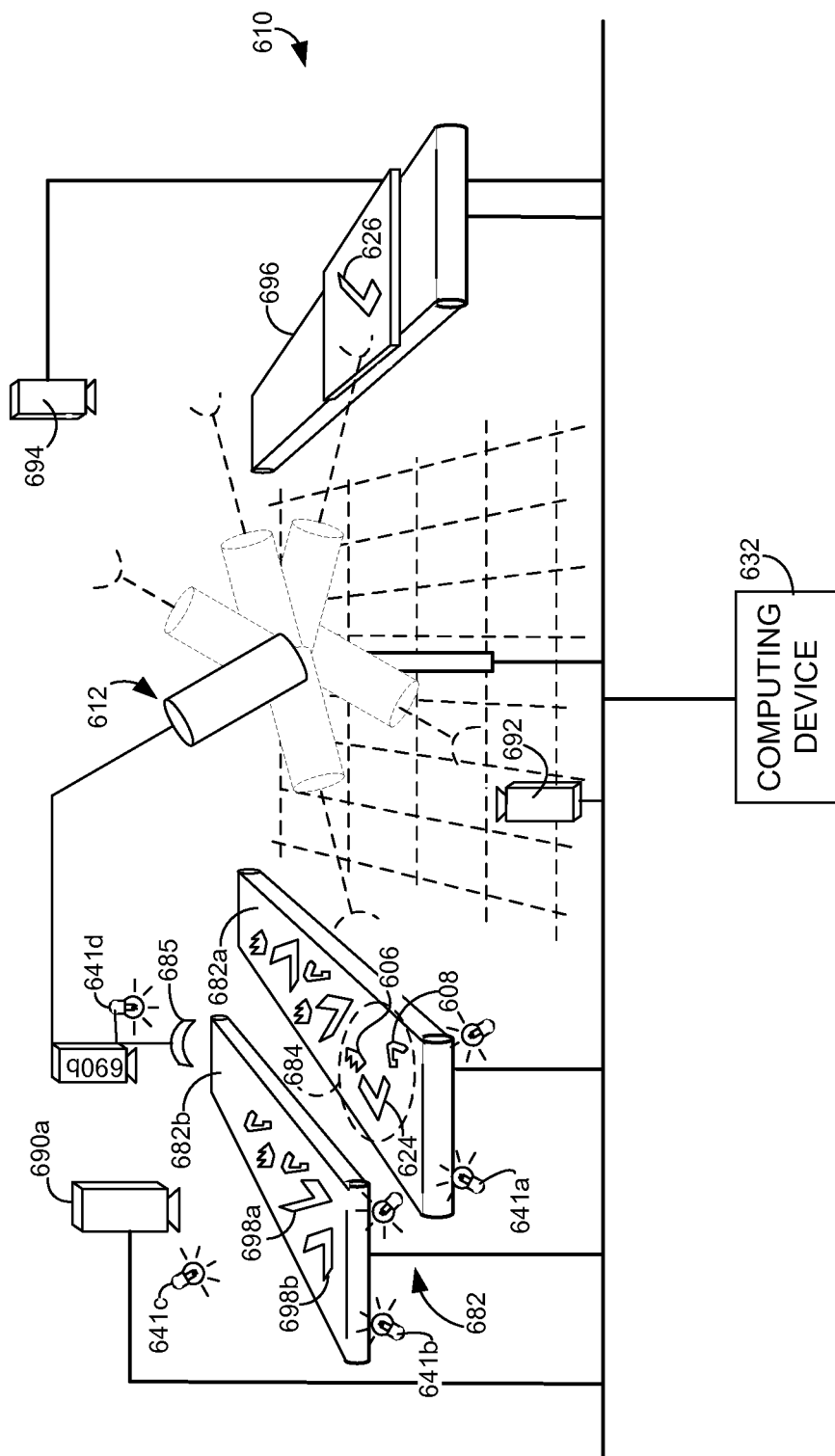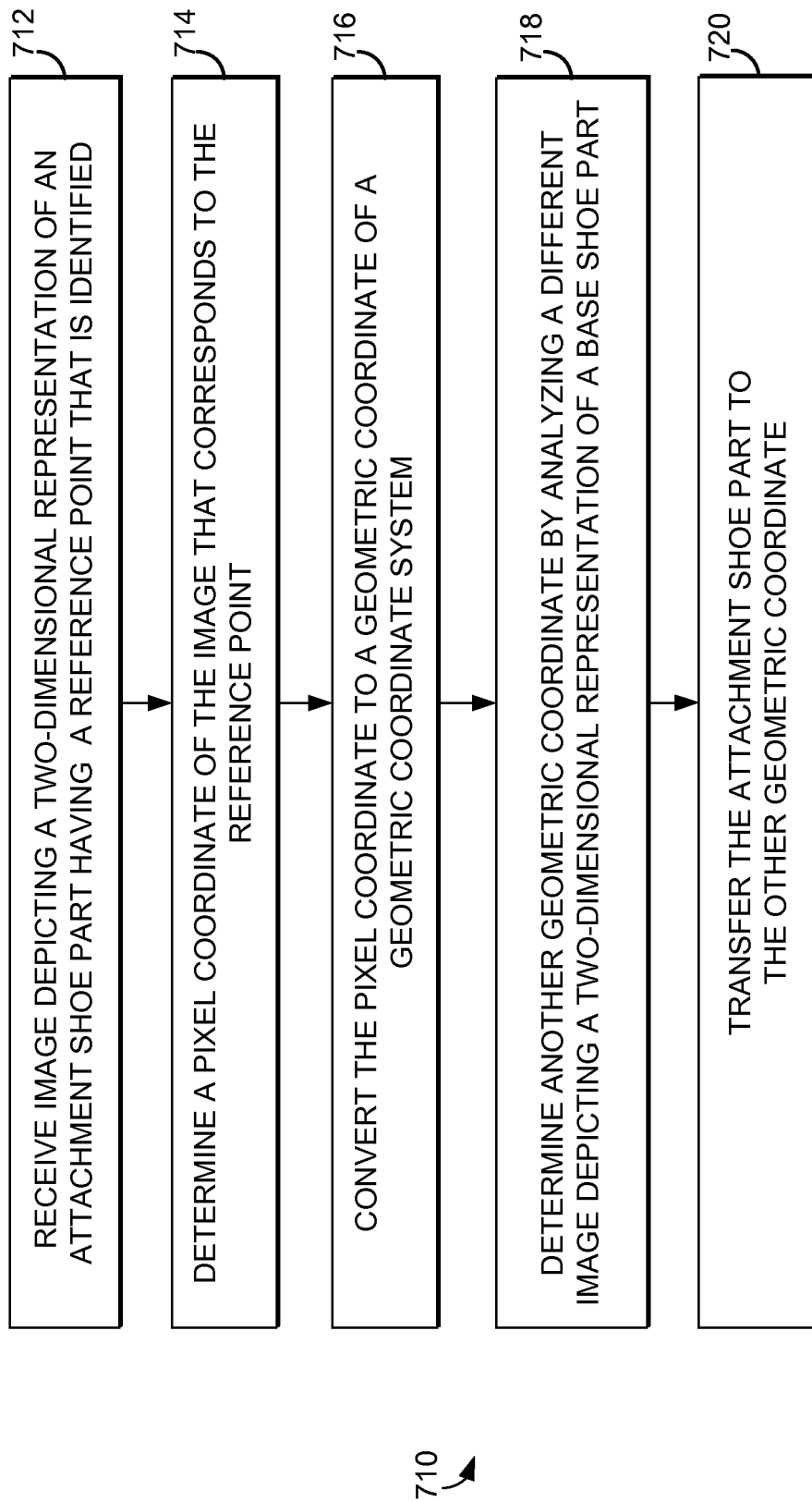RECEIVE IMAGE DEPICTING A TWO-DIMENSIONAL REPRESENTATION OF AN ATTACHMENT SHOE PART HAVING A REFERENCE POINT THAT IS IDENTIFIED

714

DETERMINE A PIXEL COORDINATE OF THE IMAGE THAT CORRESPONDS TO THE REFERENCE POINT

716

CONVERT THE PIXEL COORDINATE TO A GEOMETRIC COORDINATE OF A GEOMETRIC COORDINATE SYSTEM

718

DETERMINE ANOTHER GEOMETRIC COORDINATE BY ANALYZING A DIFFERENT IMAGE DEPICTING A TWO-DIMENSIONAL REPRESENTATION OF A BASE SHOE PART

720

TRANSFER THE ATTACHMENT SHOE PART TO THE OTHER GEOMETRIC COORDINATE

710

FIG. 7.

RECEIVE IMAGE DEPICTING A TWO-DIMENSIONAL REPRESENTATION OF AN ATTACHMENT SHOE PART HAVING A REFERENCE POINT THAT IS IDENTIFIED — 812

DETERMINE A PIXEL COORDINATE OF THE IMAGE THAT CORRESPONDS TO THE REFERENCE POINT — 814

CONVERT THE PIXEL COORDINATE TO A GEOMETRIC COORDINATE OF A GEOMETRIC COORDINATE SYSTEM — 816

DETERMINE ANOTHER GEOMETRIC COORDINATE BY ANALYZING A DIFFERENT IMAGE DEPICTING A TWO-DIMENSIONAL REPRESENTATION OF A BASE SHOE PART — 818

TRANSFER THE ATTACHMENT SHOE PART TO THE OTHER GEOMETRIC COORDINATE — 820

TRANSFER THE ATTACHMENT SHOE PART TO THE OTHER GEOMETRIC COORDINATE — 822

810

FIG. 8.

MEMORY 912

PROCESSOR(S) 914

PRESENTATION COMPONENT(S) 916

I/O PORT(S) 918

I/O COMPONENTS 920

POWER SUPPLY 922

910

900

FIG. 9.

FIG. 10.

FIG. 11.

VACUUM
FORCE

13.

3102

3103

3112

3116

3114

3150

3142

3144

3152

3158

3138

3140

3160

VACUUM
FORCE

FIG. 12.

3306

3306

3106

3302

3302

3103

PRESSURIZED AIR

3304

3304

3138

FIG. 13.

VACUUM FORCE

FIG. 14.

FIG. 15.

FIG. 16.

FIG. 17.

FIG. 18.

FIG. 19.

FIG. 20.

FIG. 21.

FIG. 22.

FIG. 23.

FIG. 24.

FIG. 25.

FIG. 26.

FIG. 27.

FIG. 28.

FIG. 29.

FIG. 30.

FIG. 31.

3310

3300

FIG. 32.

3100

3200

3200   3310

3210

3212

3100

3161

3159

PLANE

3169

FIG. 33.

3310

3220

3200

3300

3240

3240

3214

3210

FIG. 34.

3160

3161

3159   3160   3212

PLANE

VACUUM
FORCE

DIRECTION
OF MOVEMENT

32600

32602
POSITION THE MANUFACTURING TOOL PROXIMATE A FIRST PART

32604
GENERATE A VACUUM FORCE

32606
TEMPORARILY MAINTAIN THE FIRST PART IN CONTACT WITH THE MANUFACTURING TOOL

32608
TRANSFER THE FIRST PART TO A SECOND PART

32610
RELEASE THE FIRST PART FROM THE MANUFACTURING TOOL

32612
POSITION THE MANUFACTURING TOOL SUCH THAT THE WELDER'S DISTAL END IS PROXIMATE THE FIRST PART

32614
APPLY ULTRASONIC ENERGY THROUGH THE WELDER'S DISTAL END TO JOIN THE FIRST PART TO THE SECOND PART

FIG. 35.

AUTOMATED IDENTIFICATION AND ASSEMBLY OF SHOE PARTS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application Ser. No. 14/267,503, entitled "AUTO-MATED IDENTIFICATION AND ASSEMBLY OF SHOE PARTS" is a Continuation Application of co-pending U.S. application Ser. No. 13/299,872, filed Nov. 18, 2011, and entitled "AUTOMATED IDENTIFICATION AND ASSEMBLY OF SHOE PARTS." The entirety of the aforementioned application is incorporated by reference herein.

BACKGROUND

Manufacturing a shoe typically requires various assembly steps, such as forming, placing, and assembling several parts. Some methods of completing these steps, such as those that rely heavily on manual execution, can be resource intensive and can have a high rate of variability.

SUMMARY

This summary provides a high-level overview of the disclosure and of various aspects of the invention and introduces a selection of concepts that are further described in the detailed-description section below. This summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used as an aid in isolation to determine the scope of the claimed subject matter.

In brief and at a high level, this disclosure describes, among other things, the manufacturing and assembly of a shoe, such as an automated placement and attachment of shoe parts. For example, a part-recognition system analyzes an image of a shoe part to identify the part and determine a location of the part. Once the part is identified and located, the part may be manipulated in an automated manner. For example, a first identified part may be placed at a desired location on second identified part using a manufacturing tool. Further, the first identified part may be attached to the second identified part using the manufacturing tool.

An exemplary system that positions and attaches a shoe part in an automated manner may have various components, such as an image recorder that records an image depicting a representation of an attachment shoe part. The system may also comprise a computing device that: (1) identifie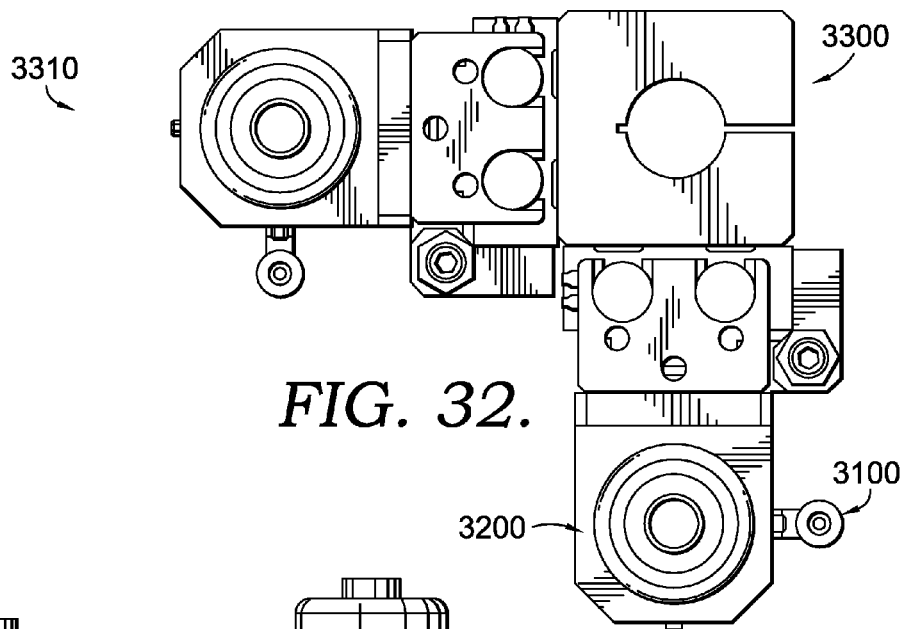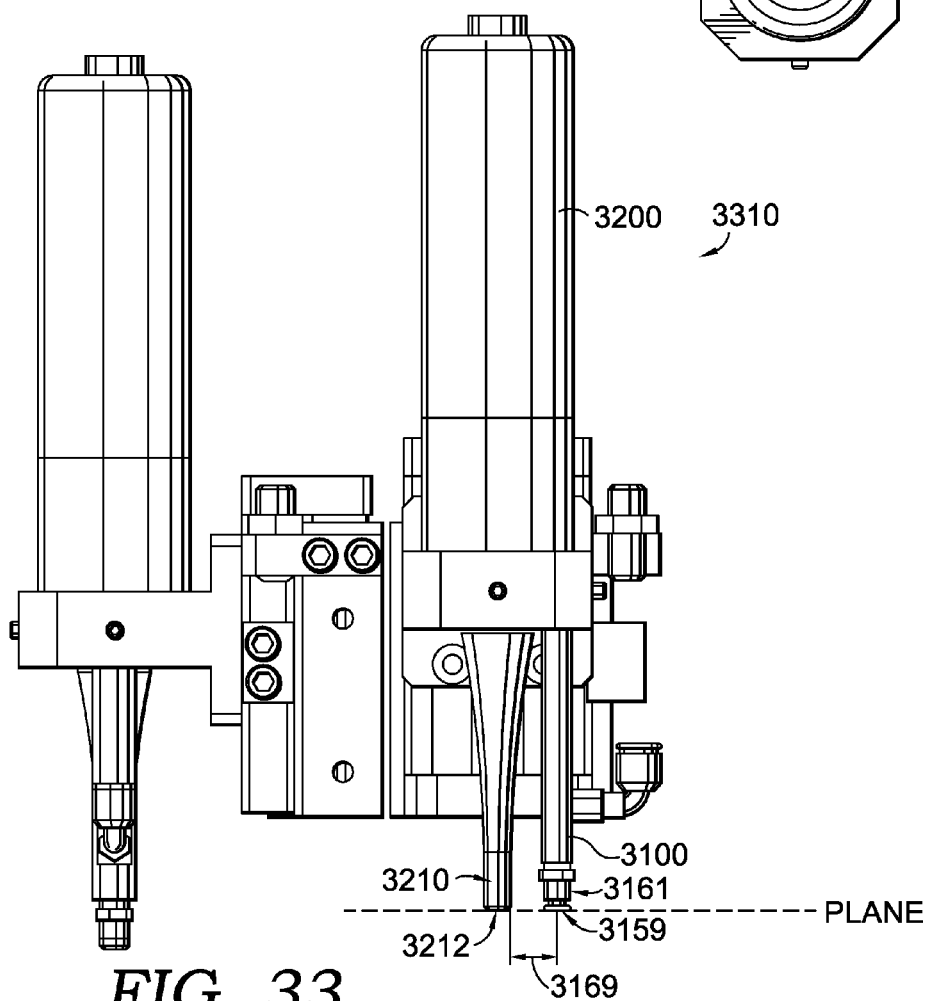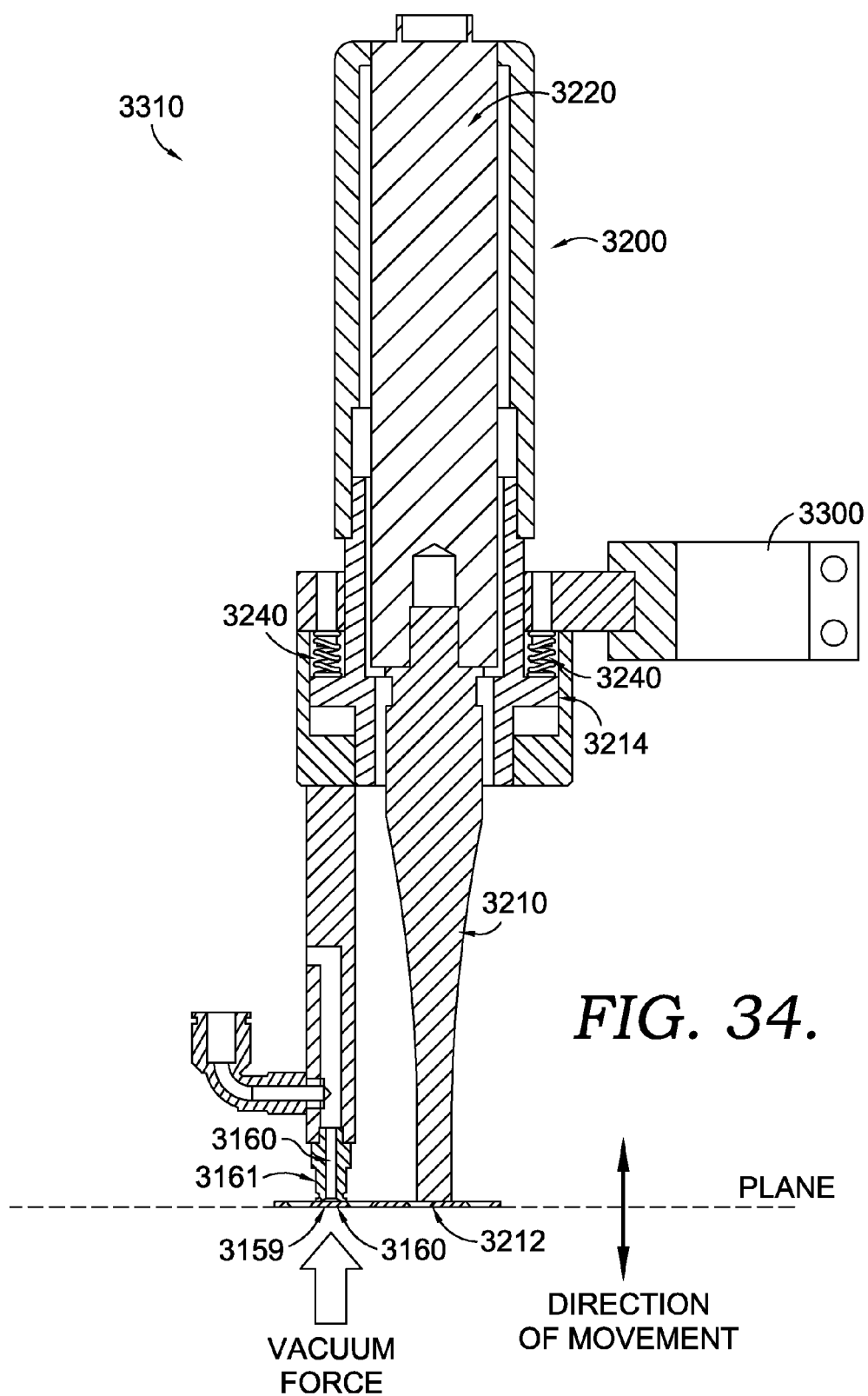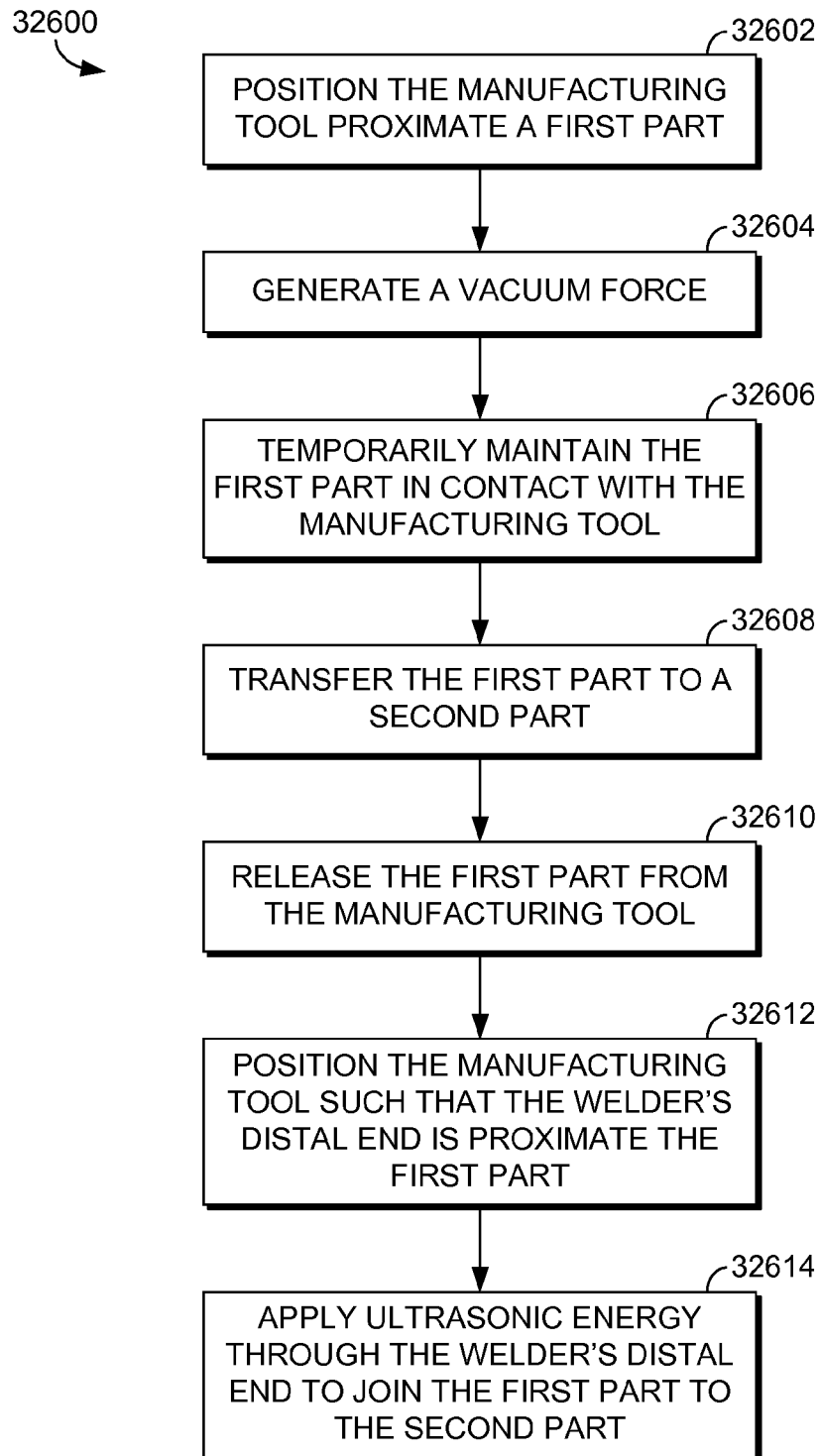s a plurality of reference features of the two-dimensional representation of the attachment shoe part; (2) determines pixel coordinates of the image that correspond to the plurality of reference features; (3) converts the pixel coordinates of the image to a geometric coordinate in a geometric coordinate system, which maps a three-dimensional space within which the attachment shoe part is positioned and a manufacturing tool operates; and (4) determines another geometric coordinate in the geometric coordinate system by analyzing a different image of the base shoe part.

The system may further comprise the manufacturing tool which may have a vacuum-powered part holder having a bottom surface adapted for contacting the attachment shoe part and an ultrasonic-welding horn comprised of a distal end adapted for contacting the attachment shoe part such that the distal end extends at least to a plane defined by the vacuum-powered part holder bottom surface. The manufacturing tool may be notified of the other geometric coordinate and transfer the attachment shoe part to the other geometric coordinate,

thereby moving the attachment shoe part to a location in the three-dimensional space at which the attachment shoe part is to be temporarily attached to the base shoe part.

An exemplary method for positioning and assembling a shoe part in an automated manner during a shoe-manufacturing process may have various steps. For example, an image may be received that depicts a two-dimensional representation of an attachment shoe part, which is to be attached to a base shoe part. The two-dimensional representation of the attachment shoe part may be associated with at least one reference feature that is identified. An identity of the image may be determined by substantially matching the image to a reference image; the reference image has at least one pre-determined reference feature. In addition, pixel coordinates of the image may be determined that correspond to the at least one pre-determined reference feature and that may be converted to a geometric coordinate of a geometric coordinate system.

Further, another geometric coordinate may also be determined by analyzing a different image of the base shoe part to which the attachment shoe part will be attached. A multi-functional manufacturing tool may be utilized to transfer the attachment shoe part to the other geometric coordinate. The multi-functional manufacturing tool may also be utilized to attach the attachment shoe part to the base shoe part

Another exemplary method of positioning and joining a plurality of manufacturing part utilizing automated identification of manufacturing parts and a manufacturing tool comprises of a vacuum-powered part holder and an ultrasonic-welding horn may also have various steps. For instance, a three-dimensional space within which a first manufacturing part is positioned and the manufacturing tool operates may be automatically identified. Further, a position of a second manufacturing part may also be automatically identified. Based on the identification of the first manufacturing part, the manufacturing tool may be positioned such that the vacuum-powered part holder is proximate to the first manufacturing part. A vacuum force may then be generated and transferred through a bottom surface of the vacuum-powered part holder sufficient to temporarily maintain the first manufacturing part in contact with at least a portion of the vacuum-powered part holder.

Continuing, based on the position of the second manufacturing part, the first manufacturing part may be transferred to the second manufacturing part. The first manufacturing part may be subsequently released from the vacuum-powered part holder so that it is in contact with the second manufacturing part. The manufacturing tool may be positioned such that the ultrasonic-welding horn is proximate the first manufacturing part, and ultrasonic energy may be applied through the ultra-sonic-welding horn, where the ultrasonic energy may be effective for joining the first manufacturing part with the second manufacturing part.

BRIEF DESCRIPTION OF THE DRAWINGS

Illustrative examples of the present invention are described in detail below with reference to the attached drawing figures, wherein:

FIG. 1A depicts a schematic diagram of an exemplary system for shoe part identification in accordance with the present invention;

FIG. 1B illustrates exemplary shoe-part references that may be generated and analyzed in accordance with the present invention;

FIG. 2 depicts a schematic diagram of an exemplary system for shoe-part identification in accordance with the present invention;

FIG. 3 depicts a flow diagram of a method for analyzing an image of a shoe part;

FIG. 4 depicts a schematic diagram of an exemplary image-recording system;

FIGS. 5 and 6 depict a respective schematic diagram of an exemplary system for carrying out shoe-manufacturing methods;

FIGS. 7 and 8 depict a respective flow diagram of a method for analyzing an image of a shoe part;

FIG. 9 depicts a block diagram of an exemplary computing device that may be used with systems and methods in accordance with the present invention;

FIG. 10 depicts a top-down view of an exemplary vacuum tool, in accordance with embodiments of the present invention;

FIG. 11 depicts a front-to-back perspective cut view along a cut line that is parallel to cutline 3-3 of the vacuum tool in FIG. 10, in accordance with aspects of the present invention;

FIG. 12 depicts a front-to-back view of the vacuum tool along the cutline 3-3 of FIG. 10, in accordance with aspects of the present invention;

FIG. 13 depicts a focused view of the vacuum generator as cut along the cutline 3-3 from FIG. 10, in accordance with aspects of the present invention;

FIG. 14 depicts an exemplary plate comprised of the plurality of apertures, in accordance with aspects of the present invention;

FIGS. 15-24 depict various aperture variations in a plate, in accordance with aspects of the present invention;

FIG. 25 depicts an exploded view of a manufacturing tool comprised of a vacuum tool and an ultrasonic welder, in accordance with aspects of the present invention;

FIG. 26 depicts a top-down perspective view of the manufacturing tool previously depicted in FIG. 25, in accordance with aspects of the present invention;

FIG. 27 depicts a side-perspective view of the manufacturing tool previously depicted in FIG. 25, in accordance with aspects of the present invention;

FIG. 28 depicts an exploded-perspective view of a manufacturing tool comprised of six discrete vacuum distributors, in accordance with aspects of the present invention;

FIG. 29 depicts a top-down perspective of the manufacturing tool previously discussed with respect to FIG. 28, in accordance with exemplary aspects of the present invention;

FIG. 30 depicts a side perspective of the manufacturing tool of FIG. 28, in accordance with aspects of the present invention;

FIG. 31 depicts a manufacturing tool comprised of a vacuum generator and an ultrasonic welder, in accordance with aspects of the present invention;

FIG. 32 depicts a top-down perspective of the manufacturing tool of FIG. 31, in accordance with aspects of the present invention;

FIG. 33 depicts a side perspective of the manufacturing tool of FIG. 31, in accordance with aspects of the present invention;

FIG. 34 depicts a cut side perspective view of a manufacturing tool comprised of a single aperture vacuum tool and an ultrasonic welder, in accordance with aspects of the present invention; and

FIG. 35 depicts a method for joining a plurality of manufacturing parts utilizing a manufacturing tool comprised of a vacuum tool and an ultrasonic welder, in accordance with aspects of the present invention.

DETAILED DESCRIPTION

The subject matter of certain aspects of the present invention is described with specificity herein to meet statutory requirements. But the description itself is not intended to define what is regarded as an invention, which is what the claims do. The claimed subject matter may comprise different elements or combinations of elements similar to the ones described in this document, in conjunction with other present or future technologies. Terms should not be interpreted as implying any particular order among or between various elements herein disclosed unless explicitly stated.

In brief and at a high level, this disclosure describes, among other things, the manufacturing and assembly of a shoe, such as an automated placement and attachment of shoe parts. For example, a part-recognition system analyzes an image of a shoe part to identify the part and determine a location of the part. Once the part is identified and located, the part may be manipulated in an automated manner. For example, a first identified part may be placed at a desired location on second identified part using a manufacturing tool. Further, the first identified part may be attached to the second identified part using the manufacturing tool.

A. Automated Identification of Shoe Parts

Subject matter described herein relates to an automated placement of a shoe part, and FIG. 1A depicts an exemplary system 10 that may perform various actions in a shoe-manufacturing process. For example, a shoe part 12 may be provided at a supply station 14 together with several other shoe parts. Supply station 14 may provide only a single type of part or multiple types of parts that are identified individually by system 10. Supply station 14 may comprise a conveyor belt, a table, a robotic arm, or any other device that can make shoe part 12 available for identification and/or manipulation in accordance with the present invention. An automated tool 16 may pick up the shoe part 12 from the supply station 14, and the shoe part 12 may be transferred to an assembly station 18 by a multi-functional manufacturing tool 20. The multi-functional manufacturing tool 20 may comprise a part-pickup portion, a part-transfer portion, and/or a part-attachment portion. As used throughout this application, the terms part-pickup tool/apparatus, part-transfer tool/apparatus, part-attachment or attachment tool/apparatus may comprise different names for the portions of the multi-functional manufacturing tool 20 and may be used interchangeably with the term multi-functional manufacturing tool 20. The multi-functional manufacturing tool 20 will be discussed in greater depth below.

A ghost depiction 21 of part-transfer apparatus is depicted to illustrate that the part-transfer apparatus may move to various positions. Moreover, various arrows 30a-d are depicted that show possible movement directions or rotations of respective components of part-transfer apparatus 20. Part-transfer apparatus 20 and the movement directions and rotations depicted by FIG. 1A are exemplary only. For example, arrows 30a and 30d indicate that respective arms of part-transfer apparatus 20 may rotate, whereas arrows 30b and 30c indicate that respective arms may move vertically or horizontally (e.g., in a telescoping manner). Although not depicted, arms of part-transfer apparatus may also be comprised of articulating joints that enable additional ranges of motion of part-transfer apparatus 20. The shoe part 12 that is transferred may function as a base shoe part 24 at the assembly station 18. Alternatively, the shoe part 12 that is transferred may be attached to a base shoe part 24 that is already positioned at the assembly station 18.

When identifying and/or placing shoe part **12** by part-transfer apparatus **20**, one or more cameras **22a-f** may record images of the shoe part **12** that may be used to recognize the shoe part **12**. The cameras **22a-f** may be arranged at various positions in system **10**, such as above a part supply station (e.g., **22a**), on part-transfer apparatus **20** (e.g., **22b**), along a floor **26** (e.g., **22c** and **22d**), and/or above assembly station **18** (e.g., **22e** and **22f**). In addition, the cameras **22a-f** may be arranged at various perspectives, such as vertical (e.g., **22b**, **22c**, **22d**, and **22e**), horizontal (e.g., **22f**), and angled (e.g., **22a**). The number, location, and/or orientation of cameras **22a-f** may vary beyond the example illustrated in FIG. **1A**.

The images may be used to determine a position and/or orientation of the shoe part **12** relative to part-transfer apparatus **20** and a position to which shoe part **12** is to be transferred. Once the shoe part **12** has been recognized, other shoe-manufacturing processes may be carried out in a manual and/or an automated fashion, such as transferring the shoe part, attaching the shoe part via any attachment method, cutting the shoe part, molding the shoe part, etc.

In a further aspect, information (e.g., shoe-part identity and orientation) obtained by analyzing images of the shoe part **12** may be combined with information derived from other shoe-part analysis systems in order to carry out shoe-manufacturing processes. For example, a three-dimensional (3-D) scanning system may derive information (e.g., shoe-part surface-topography information, shoe-part-size information, etc.) from scans of the shoe part (or from scans of another shoe part that is assembled with the shoe part), and the 3-D-system-derived information may be combined with the shoe-part-identity and/or shoe-part orientation information. That is, the 3-D-system-derived information may be determined upstream and communicated downstream to system **10** (or vice versa).

Information that is combined from different systems may be used in various manners. In an exemplary aspect, if system **10** is used to attach shoe part **12** onto shoe part **24**, information obtained from another system may be used to instruct and carry out an attachment method. For example, an amount of pressure may be calculated (based on information provided by another system) that is recommended to be exerted against the shoe part **12** in order to sufficiently attach the shoe part to one or more other shoe parts **24**. Such pressure measurements may be dependent on various factors determined and/or communicated from another system, such as a size (e.g., thickness) of the shoe part and/or a number of shoe parts (e.g., layers) that are being attached.

Computing device **32** may help execute various operations, such as by analyzing images and providing instructions to shoe-manufacturing equipment. Computing device **32** may be a single device or multiple devices, and may be physically integrated with the rest of system **10** or may be physically distinct from other components of system **10**. Computing device **32** may interact with one or more components of system **10** using any media and/or protocol. Computing device **32** may be located proximate or distant from other components of system **10**.

Light-emitting devices **28** may be positioned throughout system **10** and may be used to enhance a contrast of shoe part **12** that may be useful when an image of shoe part **12** is used to recognize shoe part **12**. Light-emitting devices may be incandescent bulbs, fluorescent devices, LEDs, or any other device capable or emitting light. A light-emitting device may be positioned in various locations, such as near and/or integrated into supply station **14** or part-pickup tool **16**. Additionally, a light-emitting device may be positioned near or integrated into assembly station **18**. Moreover, light-emitting

devices may be positioned throughout the space that surrounds part-transfer apparatus **20**, part-pickup tool **16**, part supply station **14**, assembly station **18**, and cameras **22a-f**. Varying numbers, types, and positions of light emitting devices may be used in accordance with the present invention. Light emitting devices may be selected based upon the spectrum of light emitted and how that spectrum interacts with spectrums reflected by shoe part **12**, supply station **14**, assembly station **18**, part-pickup tool **16**, etc. For example, light-emitting devices may provide full-spectrum light and/or partial-spectrum light (e.g., colored light).

Various aspects of FIG. **1A** have been described that may also be applicable to other systems described in this disclosure, such as systems depicted in FIGS. **2**, **4**, **5**, and **6**. Accordingly, when describing these other systems, reference may also be made to FIG. **1A** and aspects described in FIG. **1A** may also apply in these other systems.

As indicated with respect to FIG. **1A**, some aspects of the invention are directed to using an image of a shoe part to identify certain shoe-part information, such as an identity of the shoe part and an orientation of the shoe part (e.g., position and rotation). The shoe-part identity and shoe-part orientation may then be used to carry out various shoe-manufacturing steps (e.g., placement, attachment, molding, quality control, etc.). Accordingly, certain processes may be executed before the image is recorded in order to facilitate shoe-part-image analysis, and reference is made to FIG. **1B** to describe such aspects.

FIG. **1B** illustrates various depictions **1010a-d**, each of which provides one or more exemplary shoe-part reference patterns or models (hereinafter known as shoe-part references). For example, depiction **1010a** provides an exemplary shoe-part reference **1012a**, and depiction **1010b** provides a different shoe-part reference **1014a**. Depictions **1010a-d** may represent data that is maintained in a computer-storage medium and is retrievable to execute computing functions. For example, depictions **1010a-d** may be stored in a computer-storage media as reference models or patterns and retrieved in order to be viewed on a computing output device (e.g., computer display monitor).

Shoe-part references **1012a** and **1014a** may be determined and/or created using various techniques, such as by using a computer-assisted drawing program, an automatic shape-outlining computer program, or other boundary-determination computer program. For example, an electronic image of a shoe part may be recorded and analyzed by the automatic shape-outlining computer program, which automatically traces boundaries or perimeters of shapes that comprise the shoe part. In another aspect, shapes depicted in an electronic image of a shoe part may be manually traced using a computer-drawing application. In another example, a shoe part and/or a boundary associated therewith may be manually drawn using a computer-drawing application. FIG. **1B** depicts that shoe-part references may be comprised of a shoe-part perimeter or boundary (e.g., **1030**), as well as an interior portion (e.g., **1032**) bound by the perimeter **1030**. As previously indicated, once created, a shoe-part reference may be electronically stored (e.g., item **234** in FIG. **2**) and used in various manners, such as to analyze shoe-part images.

In one aspect, a shoe-part reference (e.g., shoe-part reference **1012a**) is created such that it may be scaled to correspond to a multiple of different shoe sizes. For example, a shoe-part reference corresponding to a model size (i.e., a model size for females and a model size for males) is created and all other matching shoe-part references are scaled off of the shoe-part reference corresponding to the model size. A shoe-part reference may be scaled up to, for example, five

times to account for the different sizes. Further, the shoe-part reference can be scaled to allow for expansion and/or shrinkage for any particular size.

Continuing, references 1012a and 1014a may be used to determine reference information, which may be subsequently used to assemble shoe parts. For example, an attachment shoe part (e.g., 224 in FIG. 2) may be positioned relative to a base shoe part (e.g., 226 in FIG. 2); however, before the attachment shoe part is positioned, it may be helpful to determine a placement location at which the attachment shoe part should be positioned.

As such, in an illustrative aspect, depiction 1010c comprises a reference 1014b, which represents a physical boundary of a base shoe part, and a reference 1012b, which represents a physical boundary of an attachment shoe part. In an exemplary aspect, reference 1012b may be positioned to overlay reference 1014b and may be aligned with at least a portion of the reference 1014b. For example, boundary 1012b may be manually and/or automatically positioned (e.g., drag via input device) in a manner that is consistent with how an attachment shoe part would be arranged onto a base shoe part when the attachment shoe part will be attached to the shoe part. As such, depiction 1010d illustrates a digitally rendered assembly of references 1016, which is comprised of reference 1012c aligned with reference 1014c in a position consistent with an attachment position.

In a further aspect of the invention, a reference feature 1020 may be identified that aligns a portion of reference 1012c with a portion of reference 1014c. As such, each of references 1012c and 1014c comprises respective reference features that are generally aligned with one another. These respective reference features are shown in depiction 1010c and are identified by reference numerals 1021 and 1022. For example, a respective reference feature may be used to determine an orientation (e.g., position and rotation) of a shoe part, as well as a portion of the shoe part that aligns with another shoe part.

Now described is FIG. 2, in which an exemplary shoe-manufacturing system 210 is depicted. System 210 may have a combination of shoe-manufacturing equipment and computing devices, which may assist in determining automated operations of the equipment. Operations carried out in system 210 may facilitate manipulation of shoe part 224 and shoe part 226, such as by transferring shoe part 224 and attaching shoe part 224 onto shoe part 226. For example, shoe parts 224 and 226 may comprise two different pieces of flexible material, which are attached to one another to form part of a shoe upper. Shoe parts 224 and 226 may comprise the same or different types of flexible material, such as textiles, leathers, TPU materials, etc. Shoe parts 224 and 226 may be physical structures of the completed shoe and/or a component, such as an adhesive film, that may be used to join shoe components during the shoe manufacturing process.

A part-transfer apparatus 212, cameras 214a and 214b, and conveyor 222 are examples of shoe-manufacturing equipment. A grid 225 is depicted in FIG. 2 (in broken lines) to convey that one or more items of the shoe-manufacturing equipment have a known position within a coordinate system (e.g., geometric coordinate system mapping a 3-D space within which the equipment is positioned). Other items, such as shoe parts, may be moved to known distances within the coordinate system. Although for illustrative purposes grid 225 only depicts two coordinates, axis arrows 223 depict three axes.

Image analyzers 216a and 216b and dimension converter 218 represent operations and/or modules that may be carried out by a computing device. Moreover, FIG. 2 depicts that the shoe-manufacturing equipment may communicate with (i.e.,

be networked with) computing devices that execute the depicted operations by way of a network connection 227. For example, as will be described in more detail below, image analyzers 216a and 216b may evaluate images recorded by cameras 214a and 214b to recognize shoe parts being utilized in the shoe manufacturing process. In addition, image analyzers 216a-b and dimension converter 218 communicate instructions to part-transfers apparatus 212. One example of this type of vision recognition system includes Cognex® machine vision systems.

Components depicted in system 210 cooperate in different ways to assist in carrying out various steps of a shoe-manufacturing method. For example, some components of system 210 may operate collectively as part of a two-dimensional ("2-D") part-recognition system, which is used to determine various shoe-part characteristics, such as shoe-part identity and shoe-part orientation (e.g., placement and rotation) relative to part-transfer apparatus 212. For example, a part-recognition system may comprise cameras 214a-b, image analyzers 216a-b, shoe-part datastore 220, dimension converter 218, and some or all of part-transfer apparatus 212.

A part-recognition system may be used in various manners within a shoe manufacturing process. For example, a part-recognition system may be used to execute a method 310 that is outlined in FIG. 3. Method 310 relates to identifying a shoe part and determining an orientation (e.g., geometric position and degree of rotation) of the shoe part. When an identity and orientation of a shoe part is known or determined, the shoe part can be manipulated (e.g., transferred, attached, cut, molded, etc.) in an automated manner. In describing FIG. 3, reference will also be made to FIG. 2 and FIG. 4.

At step 312, an image is recorded that depicts a representation of a shoe part. For example, an image may be recorded by camera 214a or 214b and communicated to an image analyzer 216a or 216b. Exemplary images 228 and 230 are illustrated in image analyzers 216a and 216b (respectively), and each image depicts a two-dimensional ("2-D") representation 232 and 233 of a respective shoe part.

In step 314, an outline or perimeter of the representation as depicted in the image is recognized. For example, once image analyzer 216a acquires image 228, image analyzer 216a recognizes a perimeter or outline of the 2-D representation 232 depicted in image 228. Perimeter or outline recognition may be enhanced using various techniques, such as by providing a background surface that highly contrasts a part depicted in the image, as well as by positioning various environment lighting elements (e.g., full-spectrum light-emitting devices). For example, if a surface of the shoe part that will be captured in the image is grey, a background surface (e.g., surface of a supply station, a part-pickup tool, or an assembly station) may be colored yellow in order to create a contrast in the image between the outline of the part and the background. In one aspect, shoe-part inward-facing surfaces (i.e., a side of the shoe part that may face inward and towards a wearer's foot when assembled into a shoe) and background surface may be manufactured (i.e., intentionally made) to comprise known contrasting colors.

Additional tools may be used to assist with recognizing a perimeter or outline of a representation. For example, system 210 may comprise light-emitting devices 241a and 241b that illuminate the shoe part from various sources. As described with respect to FIG. 1A, light-emitting devices may be arranged in various positions throughout system 210. For example, surface 229 may be illuminated with device 241a or backlit with light 241b, thereby enhancing a contrast between surface 229 and part 224 to render part 224 more recognizable to the 2-D recognition system. That is, if part 224 is illumi-

nated or backlit when image **228** is captured, a better contrast may appear in image **228** between representation **232** and other portions of the image. A full-spectrum light may be used for enhancing part recognition of parts having various colors. Alternatively, a color of the light may be customized based on a color of part **224** and/or the color of supply station and/or assembly station. For example, a red light may be used to enhance a contrast between parts and a supply assembly station that are black or white.

Next, at step **316**, image analyzer **216a** may determine a plurality of reference features associated with the 2-D representation **232** depicted in image **228**. For instance, the reference features may comprise a number of spaced lines and/or points that define the outline or perimeter of the 2-D representation. The spacing between adjacent reference features may be variable. For instance, the spacing between reference features for smaller-sized shoe parts may be less than the spacing between reference features for larger-sized shoe parts to allow for more precision. Each reference feature may be comprised of a variable number of pixels.

An identity of a boundary of the 2-D representation **232** may be recognized using various techniques. For example, shoe-part representation **232** may be compared to various known or model shoe-part references **234-236**, which are stored in shoe-part datastore **220** in order to determine the identity of the shoe-part representation **232**.

Shoe-part datastore **220** stores information **238**, which is shown in an exploded view **240** for illustrative purposes. As an example, exploded view **240** depicts a plurality of known shoe-part references **234-236** that may be used to recognize the identity of the 2-D representation **232**. Shoe-part references **234-236** may be associated with pre-determined reference features (e.g., **242** and **244**) as outlined above with respect to FIG. 1B, which may be used when assembling a respective shoe part into a shoe. Such reference features may be pre-determined based on various factors, such as a known position of a shoe part among an assembly of shoe parts. For example, when incorporated into a shoe, shoe part **224** is assembled at a position with respect to shoe part **226**. As such, this position may be measured and used to instruct shoe-manufacturing equipment on positioning and attachment of shoe part **224**.

As depicted in FIG. **2**, shoe-part references **234-236** form various 2-D shapes. In an aspect of the invention, the pre-determined reference features may comprise any number of features associated with the perimeter or outline of the shoe-part references **234-236**. For example, a reference feature may comprise a specified proportion between different sides of the 2-D shape. As well, a reference feature may comprise a junction point between two adjacent sides of the 2-D shape. Creating pre-determined reference features along a perimeter of the shape can reduce variability that may be created when shoe parts are aligned and connected.

The image analyzer **216a** may recognize an identity of the 2-D representation **232** by identifying at least one shoe-part reference of the plurality of shoe-part references **234-236** that substantially matches the 2-D shoe-part representation **232**. For example, the image analyzer **216a** may recognize the identity of the 2-D shoe-part representation **232** by identifying at least one pre-determined reference feature of a shoe-part reference that substantially matches the at least one reference feature of the 2-D representation **232**.

Once a shoe-part representation (e.g., **232**) is substantially matched to a known shoe-part reference (e.g., **234**), the pre-determined reference feature(s) may be used to analyze an image that depicts the representation. For example, image analyzer **216a** has retrieved a recognized entity **249** based on

shoe-part reference **234**, which was substantially matched to 2-D representation **232**. As depicted, recognized entity **249** has a boundary and pre-determined reference feature(s). Accordingly, when the descriptions of FIGS. 1B and **2** are collectively considered, an exemplary method may comprise various steps. For example, model references (e.g., **1012a** and **1014a**) and their corresponding pre-determined reference features (e.g., **1021** and **1022**) are determined and electronically maintained, such as in datastore **220**. A recorded image (e.g., **228** and **230**) may then be substantially matched to a model reference by substantially matching reference features of the recorded image with pre-determined reference features of the model. This reference information may be mathematically depicted with respect to a known reference system.

At step **318**, a rotation of the representation (as depicted in the image) and pixel coordinates of the image are identified. To illustrate one manner in which image analyzer **216a** utilizes recognized entity **249** to execute step **318**, information **250** is depicted in an exploded view **252**. Exploded view **252** depicts image **254** that is identical to image **228**. For example, image **254** and image **228** may be the same data, or image **254** may be a copy of image **228**. Image **254** is depicted respective to a coordinate system **256**, which maps pixels of image **254**. Recognized entity **249** is applied to image **254**, such as by substantially centering image **254** within the boundaries of recognized entity **249** and aligning by reference feature(s) **258**. As such, pixel coordinates of image **254** can be determined that belong to coordinate system **252**. In addition, a degree of rotation (i.e., Θ) of the shoe-part representation (as depicted in image **254**) is determined by measuring an angle between reference lines **260** and **262**.

The pixel coordinates and degree of rotation that are extracted from the image may be used to instruct part-transfer apparatus **212**. That is, image **228** may be recorded by camera **214a** when shoe part **224** is oriented (i.e., positioned and rotated) somewhere in the 3-D space in which part-transfer apparatus **212** operates. Examples of positions at which shoe part **224** may be located include a part supply station, an assembly station, and/or held by part-transfer apparatus **212**. Accordingly, when certain inputs are provided, pixel coordinates of image **228** may be converted by dimension converter **218** to a geometric coordinate **205** of the system represented by grid **225**. Accordingly, in step **320** of method **310** the pixel coordinates may be converted to a geometric coordinate.

Inputs utilized by dimension converter **218** may comprise measurement values describing system **210**, camera **214a**, and part-transfer apparatus **212**. Examples of such measurement values are relative positions (i.e., zero positions) of camera **214a** and of part-transfer apparatus **212**; a number of pixels of the X and Y coordinates of system **256**; a distance between camera **214a** and part **224**; a chip size of the CCD in camera **214a**; a lens focal length; a field of view; a pixel size; and a resolution per pixel. These inputs may vary depending on the capabilities of the equipment used in system **210** and some inputs may have a direct bearing on where equipment may be positioned within system **210**. For example, the strength of camera **214a** may have a bearing on where part **224** should be positioned (relative to camera **214a**) when camera **214a** will record an image of part **224**. To further illustrate a relationship between various inputs used to convert a pixel coordinate to a geometric coordinate, FIG. **4** depicts a schematic diagram of a system with which an image may be recorded and analyzed.

The geometric coordinate generated by dimension converter **218** can be used to report a position of shoe part **224** to part-transfer apparatus **212**. Moreover, the degree of rotation can be used to determine to what extent shoe part **224** may

need to be rotated by part-transfer apparatus **212** in order to be properly aligned for subsequent manipulation (e.g., attachment to another shoe part, cutting, painting, etc.). Accordingly, part-transfer apparatus **212** may comprise a part-pickup tool that enables part-transfer apparatus **212** to acquire part **224** from a part-supply area and temporarily hold part **224** while transferring part **224** to a new location. For example, part-transfer apparatus **212** may use a gripping structure, suction, electromagnetic forces, surface tack, or any other methodology to temporarily engage and move a shoe part.

Although the above 2-D recognition process is described by referencing shoe part **224** and image **228**, a similar analysis may be used to identify shoe part **226** and determine its orientation, thereby enabling part-transfer apparatus **212** to account for part **226** when manipulating part **224**. That is, information **270** is depicted in image analyzer **216***b* and is shown in an exploded view **272** for illustrative purposes. Exploded view **272** conveys that image **230** may be analyzed similar to image **228** to determine an orientation (i.e., geometric coordinate and degree of rotation) of part **226** based on reference feature(s) **279** and theta. Any number of shoe parts may be identified and/or positioned, either simultaneously or sequentially in accordance with the present invention.

Once respective geometric coordinates of part **224** and part **226** are known, part-transfer apparatus **212** can pick up part **224** and move part **224** to a part-position coordinate **203** that is relative to the geometric coordinate of part **226**. For example, FIG. **2** depicts multiple broken-line views of part-transfer apparatus **212** to illustrate a movement of part-transfer apparatus and a transfer of part **224**. A part-position coordinate **203** refers to a coordinate in the geometric coordinate system (e.g., the system illustrated by grid **225**) to which an attachment part (e.g., part **224**) is transferred in order to be attached to a base part (e.g., part **226**). For example, part-transfer apparatus **212** may transfer part **224** to geometric coordinate **203** to be attached to part **226**.

A part-position coordinate **203** may be determined in various ways. For example, part **226** may be a base shoe part onto which part **224** is attached, such that a position of part **224** respective to part **226** (when the parts are assembled) is known. As such, the known position may be determined by retrieving a stored reference feature, which was pre-determined using a method similar to that described with respect to FIG. **1B**. However, this position that is known may still be converted to a coordinate that is recognized by part-transfer apparatus **212** when part **226** has been positioned within a coordinate system of part-transfer apparatus **212**. That is, outside of coordinate system **225**, a position relative to part **226** at which part **224** is arranged is known, and is identified by reference numeral **277** in datastore **220**. This position is also identified in exploded view **272** in which the position is identified as "part-position location for part **224**." When an orientation of part **226** is determined, such as by executing method **310**, the point **277** (also depicted in exploded view **272**) that is respective to part **226** at which part **224** is arranged can be converted to a geometric coordinate **203** within system **225**, thereby calculating part-position coordinate **203**. Accordingly, in an exemplary aspect, part-position **203** is converted to a geometric coordinate based in part on reference feature **1022**, which was described with reference to FIG. **1B**.

In a further aspect, once part-position point **203** is determined, part **224** can be transferred to the part-position coordinate **203** based on the reference information determined with respect to part **224** (e.g., **1021** in FIG. **1B**). For example, pixel coordinates and orientation may be derived from image **228** (as described above) and may be converted to a geometric

coordinate (e.g., **205**). Calculations may then be made to transfer part **224** to point **203**. For example, a virtual robot end effector may be created based on the geometric data (e.g., **203** and **205**) and may be moved from point **205** to point **203**. While these steps are depicted graphically in FIG. **2** for illustrative purposes, these steps could also be executed mathematically by solving sequential conversion algorithms.

Accordingly, the above-described recognition process (e.g., method **310**) may be used in many different scenarios within a shoe-manufacturing process. For example, once shoe part **224** has been positioned respective to shoe part **226**, shoe part **224** can be attached to shoe part **226**, such as by stitching, adhering, and/or sonic welding. As such, in order to enable automation, a geometric coordinate **201** of the attachment point is also determined. That is, once geometric coordinates of parts **224** and **226** are known within coordinate system **225**, geometric coordinates of attachment locations can also be calculated.

An attachment-point coordinate **201** may be determined in various ways. For example, part **226** may be a base shoe part onto part **224** is attached. As such, a point of attachment onto base shoe part is known, but it still may be converted to a coordinate that is recognized by part-transfer apparatus **212**. That is, outside of coordinate system **225**, a point on part **226** at which part **224** will be attached is known, and is identified by reference numeral **274** in datastore **220**. When an orientation of part **226** is determined, such as by executing method **310**, the point **274** (also depicted in exploded view **272**) on part **226** at which part **224** is attached can be converted to a geometric coordinate **201** within system **225**. As such, an attachment process can be executed at the geometric coordinate **201**. As indicated above, although these steps are depicted graphically in FIG. **2** for illustrative purposes, these steps could also be executed mathematically by solving sequential conversion algorithms.

In one aspect, part-transfer tool **212** also may have an attachment device, which operates to attach part **224** to part **226**. Exemplary attachment devices are an ultrasonic welder, heat press, stitching apparatus, or a device that accomplishes a respective method of attachment. For instance, an ultrasonic welder may apply ultrasonic energy through an ultrasonic-welding horn in order to attach in a temporary or permanent fashion parts **224** and **226**.

The components of system **210** may be arranged in various configurations to accomplish a wide range of shoe-manufacturing processes. In addition, there may be additional components arranged into a series of stations. For example, system **210** may be comprised of cameras in addition to cameras **214***a-b*, as well as additional part-transfer apparatuses. Different types of cameras and/or part transfer apparatuses may be combined in accordance with the present invention. These additional tools may be arranged at different positions along conveyor **222** to allow additional parts to be added (e.g., added to the assembly of parts **224** and **226**) and to allow additional shoe-part manipulation.

Moreover, the cameras of system **210** may be arranged at different positions with respect to a shoe part. For example, as depicted in FIG. **1A**, cameras may be positioned above a shoe part, below a shoe part, horizontal to a shoe part, or at an angle away from a shoe part, so long as the camera position allows the geometric coordinate of the part to be calculated. One such camera position may be perpendicular to (i.e., normal to) a viewing plane. However, the camera could be positioned at an angle from the viewing plane, so long as the angle is provided as an input to the system when converting the rep-

resentation orientation to a geometric coordinate. Accordingly, system 210 may be incorporated into larger shoe-manufacturing processes.

A 2-D recognition system may be used at an initial stage to enable part-transfer apparatus 212 to position a base shoe part onto a conveyor or other part-moving apparatus. A base shoe part refers to a shoe part onto which one or more other shoe parts may be attached, and a base shoe part may be constructed of a single part or a plurality of parts that have been assembled. Accordingly, part 226 may be deemed a base shoe part onto which part 224 is attached. Parts transferred may also be foams, mesh, and/or adhesive layers, such as TPU films, ultimately used to join other parts together. Further, component parts previously affixed to one another in accordance with the present invention may be treated as a single part for subsequent identification transfer, etc.

Referring to FIG. 5, a system 510 is depicted in which a 2-D part-recognition system may be used at an initial manufacturing stage, such as when the base shoe part 526 is initially stored at a part-supply station 580, which may be comprised of various configurations. For example, a part-supply station 580 may comprise a set of stacked base shoe parts from which part-transfer apparatus 512 acquires a topmost base shoe part. Alternatively, the part-supply station may have a conveyor 582 that transfers the base shoe part to a pickup location 584 at which part-transfer apparatus 512 acquires the base shoe part. As previously described, part-transfer apparatus 512 may have a part-pickup tool 585.

Prior to transferring base shoe part 526 to conveyor 596, a camera may record an image of the base shoe part 526 to allow part-transfer apparatus 512 to determine a geometric position and rotation of the base shoe part 526. For example, a camera may record an image of the base shoe part 526 when the base shoe part 526 is next-in-line to be acquired by part-transfer apparatus 512—i.e., immediately prior to the base shoe part 526 being acquired by part-transfer apparatus 512 and when the base shoe part 526 is at pickup location 584. The camera may be an above-mounted camera 590a-b that is mounted above, and perpendicular to, the base shoe part 526. As depicted in FIG. 5, an above-mounted camera 590a-b may be mounted either apart from (e.g., 590a) or onto (e.g., 590b) part-transfer apparatus 512.

Although part-transfer apparatus 512 is illustrated to have a certain configuration depicted in FIG. 5, part-transfer apparatus may have a different configuration, such as the configuration depicted in FIG. 1A, in which a camera mounted to the part-transfer apparatus may be positionable directly above and perpendicular to base shoe part 526. Part-transfer apparatus 512 may also comprise a plurality of articulating arms that enable movement of a camera (or an acquired shoe part) to a desired angle or position.

Moreover, if the image is recorded while the base shoe part 526 is at a part-supply station (i.e., at location 584), a light-emitting device may be arranged at various positions throughout system 510. For example, a light-emitting device 541a may be positioned adjacent to or incorporated into the part-supply station 580 to provide a backlight to the base shoe part 526. Also, a light-emitting device 541b may be positioned in a space that surrounds base shoe part, such that the light-emitting device 541b illuminates base shoe part 526 from a front side.

Alternatively, part-transfer apparatus 512 may acquire base shoe part 526 before an image is recorded and position the acquired base shoe part in front of a camera. For example, a below-mounted camera 592 may be secured near a floor surface, and part-transfer apparatus 512 may position the acquired base shoe part directly above, and perpendicular to,

the below-mounted camera 512. Alternatively, part-transfer apparatus 512 may position the acquired base shoe part directly below, and perpendicular to, above-mounted cameras 590a or 594. As described above, although part-transfer apparatus 512 is illustrated to have a certain configuration depicted in FIG. 5, part-transfer apparatus may have a different configuration. For example, part-transfer apparatus 512 may have the configuration depicted in FIG. 1A. In addition, part-transfer apparatus may be comprised of a plurality of articulating arms.

If the image is recorded after the base shoe part 526 has been acquired by part-transfer apparatus, a light-emitting device 541c may be arranged at various positions. For example, a light-emitting device 541c may be incorporated into the part-transfer apparatus 512, such as behind (or incorporated into) the part-pickup tool 585, thereby providing a backlight to base shoe part 526. In addition, other light-emitting devices (e.g., 541d) positions throughout system 510 may illuminate a front side of a base shoe part that is acquired by part-transfer apparatus 512

Once an image has been recorded, a geometric position and rotation of the base shoe part may be determined using the previously described methods (e.g., method 310). The geometric position and rotation may then be used to determine a position of the base shoe part when the base shoe part is transferred to conveyor 596. For example, part-transfer apparatus 512 may execute a predetermined movement path each time it transfers base shoe part 526 from a part-supply station 580, or from in front of a camera (e.g., 590a, 592, or 594), to conveyor 596. As such, once the geometric position and rotation of the base shoe part are known, the part-transfer apparatus may determine where the base shoe part will be positioned when the predetermined movement path is executed. Alternatively, a geometric position on conveyor 596 may be predetermined, such that part-transfer apparatus 512 (or some computing device associated therewith) calculates a new movement path each time. That is, the new movement path extends from the calculated position of the base shoe part 526 (when the image is recorded) to the predetermined position on the conveyor 596. Computing device 532 may help execute various operations, such as by analyzing images and providing instructions to shoe-manufacturing equipment.

In another aspect, a 2-D recognition system may be used when base shoe part 526 has already been transferred to conveyor 596 in order to determine a geometric position and rotation of base shoe part 526 as it is arranged on conveyor 596. As such, conveyor 596 may move base shoe part along an assembly line and to a position that is beneath an above-mounted camera (e.g., 594). Once an image has been recorded by the above-mounted camera and a position of base shoe part has been determined, other shoe parts may be transferred and attached to the base shoe part.

As such, in a further aspect, a 2-D recognition system may be used after the initial stage to enable a part-transfer apparatus to position an attachment shoe part. An attachment shoe part refers to a shoe part that is to be attached to a base shoe part. Accordingly, in FIG. 2 part 224 may be deemed an attachment shoe part that is to be attached to shoe part 226.

Referring to FIG. 6, a system 610 is depicted in which a 2-D recognition system may be used to position an attachment part 624, such as when the attachment shoe part 624 is initially stored at a part-supply station 682, which may be arranged into various configurations. As previously described, a part-supply station 682 may comprise a set of stacked shoe parts from which part-transfer apparatus 612 acquires a topmost attachment shoe part. Alternatively, the part-supply station 682 may be comprised of a set of convey-

ors **682a** and **682b**, one of which transfers the attachment shoe part **624** to a pickup location **684** at which part-transfer apparatus **612** may acquire the attachment shoe part **624**.

As previously described, part-transfer apparatus **612** may have a part-pickup tool **685**. Although part-transfer apparatus **612** is illustrated to have a certain configuration depicted in FIG. **6**, part-transfer apparatus may have a different configuration, such as the configuration depicted in FIG. **1A**, or a configuration comprising a plurality of articulating arms that enable movement of a camera (or an acquired shoe part) to a desired angle or position.

The attachment shoe part **624** may be provided at the supply station **682** among a plurality of different attachment shoe parts (e.g., **606** and **608**), each of which may be attached to a respective portion of base shoe part **626**. As such, 2-D recognition system may execute a part-selection protocol, which allows the system to identify and select a desired attachment part.

In an exemplary part-selection protocol, the 2-D recognition system may be programmed to follow a predetermined order of attachment parts—i.e., attach first part **624**, followed by second part **608**, followed by third part **606**, etc. Accordingly, the 2-D recognition system may record images of all of the parts arranged among the plurality, identify each part (e.g., based on datastore **220**), and determine a geometric location of each part as it is positioned at supply station **682**. Once this position information has been determined by the 2-D recognition system, part-transfer apparatus **612** may acquire and attach each part in the predetermined order.

In another part-selection protocol, the 2-D recognition system may be programmed to transfer and attach a set of parts, regardless of the order—i.e., attach first, second, and third parts in any order. Accordingly, once images of each part (e.g., **606**, **608**, and **624**) have been analyzed to determine a geometric position, part-transfer apparatus **612** may acquire the parts in a variety of orders, as long as all of the parts are transferred to the base part **626** at some point. Moreover, the 2-D recognition system may be programmed to retrieve the parts that are positioned in a manner that allows for the most efficient transfer from the supply station **682** to base shoe part **626**. For example, if two first parts **698a** and **698b** are provided at the supply station and one of the first parts **698a** is closer than the other first part **698b** (based on respective geometric coordinates), the part-transfer apparatus **612** may be instructed to pick up the closer first part **698a** instead of the other first part **698b**. Similarly, if a first part **698a** is rotated to a degree that may need less adjustment (relative to another first part **698b**) in order to be attached to base part **626**, the part-transfer apparatus **612** may be instructed to pick up the first part **698a**. Computing device **632** may help execute various operations, such as by executing certain steps in a part-selection protocol, analyzing images, and providing instructions to shoe-manufacturing equipment.

In another exemplary aspect, parts **606**, **608**, and **624** may be arranged at part-pickup location **684** in a pre-determined configuration, such that coordinates of the pre-determined configuration may be provided to apparatus **612** to assist with part selection. That is, if a coordinate of each part **606**, **608**, and **624** is pre-determined based on how the group of parts are to be arranged (prior to being picked up), then a coordinate may not have to be calculated based on images. Or, a pre-determined coordinate may be used as a check to confirm that a calculated coordinate is accurate (e.g., within a threshold amount away from the pre-determined coordinate).

In a further aspect, a pre-determined arrangement of parts **606**, **608**, and **624** at part-pickup location **684** may match an arrangement of the parts **606**, **608**, and **624** when the parts are

attached to base part **626**. That is, each of parts **606**, **608**, and **624** may be spaced apart from one another and rotated in a manner that matches a spacing and rotation of each part when attached to base part **626**. As such, parts **606**, **608**, and **624** may be picked up, placed, and/or attached as a collective group (i.e., more than one at a time) in a manner that maintains the pre-determined arrangement (i.e., maintains the spacing and rotation).

When an image is recorded of an attachment shoe part **624** to determine an orientation of the attachment shoe part **624**, the camera may be positioned in various locations. As previously described, if the attachment shoe part **624** is positioned at the supply station **682** when the image is captured, the camera (e.g., **690b**) may be coupled directly to part-transfer apparatus **612**, or may be an above-mounted camera **690a**. Camera **690b** or **690a** may be perpendicularly oriented from shoe part **624** when the image is recorded. For example, part-transfer apparatus **612** may be comprised of one or more articulating arms that position camera **690b** above and perpendicular to shoe part **624**.

Moreover, light-emitting devices may be arranged throughout system **610** to illuminate shoe part **624** when positioned at part-supply station **682**. For example, a light-emitting device **641a** or **641b** may be positioned adjacent to, or integrated into, the supply station **682** in order to backlight the attachment shoe parts positioned on conveyors **682a** and **682b**. Also, light-emitting devices **641c** may be positioned in a space surrounding part-supply station **682** to illuminate a front side of shoe part **624**.

If the attachment shoe part **624** is retained by part-transfer apparatus **612** when the image is captured, the camera may be mounted remotely from the part-transfer apparatus **612**, such as camera **690a**, **692**, or **694**. In such an arrangement, shoe-transfer apparatus **612** may position the attachment shoe part in front of (e.g., perpendicular to a field of view of) camera **690a**, **692**, or **694**. Moreover, a light-emitting device **641d** may be integrated into the part-transfer apparatus **612**, such as behind the part-pickup tool **685**, in order to illuminate the acquired shoe parts when the image is captured.

Although some of the above methods describe analyzing a single image to determine an orientation, multiple images of a single part, which are recorded by one or more cameras, may be analyzed to derive a set of geometric coordinates that are believed to accurately represent a position of a shoe part. In such a system, the set of geometric coordinates may be averaged or otherwise combined to arrive at a final geometric coordinate.

Referring now to FIG. **7**, a flow diagram is depicted of a method **710** for positioning a shoe part in an automated manner during a shoe-manufacturing process. In describing FIG. **7**, reference is also be made to FIG. **2**. In addition, method **710**, or at least a portion thereof, may be carried out when a computing device executes a set of computer-executable instructions stored on computer storage media.

At step **712** an image (e.g., **228**) may be received depicting a two-dimensional representation (e.g., **232**) of an attachment shoe part (e.g., **224**), which is to be attached to a base shoe part (e.g., **226**), wherein the two-dimensional representation of the attachment shoe part comprises a plurality of reference features **258**. At step **714**, pixel coordinates of the image (e.g., coordinate of system **256**) are identified that correspond to the reference features. Step **716** converts the pixel coordinates of the image to a geometric coordinate (e.g., **205**) of a geometric coordinate system (e.g., **225**), which maps a three-dimensional space within which the attachment shoe part (e.g., **224**) is positioned and a part-transfer apparatus (e.g., **212**) operates. Further, at step **718**, another geometric coordinate (e.g.,

203) of the geometric coordinate system (e.g., 225) is determined by analyzing a different image (e.g., 230) depicting a two-dimensional representation (e.g., 233) of the base shoe part (e.g., 226) to which the attachment shoe part (e.g., 224) will be attached. Step 720 transfers, by the part-transfer apparatus (e.g., 212), the attachment shoe part (e.g., 224) to the other geometric coordinate (e.g., 203), thereby moving the attachment shoe part to a location in the three-dimensional space at which the attachment shoe part is to be attached to the base shoe part.

Referring now to FIG. 8, another flow diagram is depicted of a method 810 for positioning a shoe part in an automated manner during a shoe-manufacturing process. In describing FIG. 8, reference is also be made to FIG. 2. In addition, method 810, or at least a portion thereof, may be carried out when a computing device executes a set of computer-executable instructions stored on computer storage media.

At step 812 an image (e.g., 228) is received depicting a two-dimensional representation (e.g., 232) of an attachment shoe part (e.g., 224), which is to be attached to a base shoe part (e.g., 226), wherein the two-dimensional representation of the attachment shoe part comprises at least one reference feature 258. At step 814, pixel coordinates of the image (e.g., coordinate of system 256) are identified that correspond to the at least one reference feature 258. Step 816 converts the pixel coordinates of the image to a geometric coordinate (e.g., 205) of a geometric coordinate system (e.g., 225), which maps a three-dimensional space within which the attachment shoe part (e.g., 224) is positioned and a part-transfer apparatus (e.g., 212) operates. Furthermore, step 818 determines a plurality of other geometric coordinates (e.g., 203 and 202) in the geometric coordinate system by analyzing a different image (e.g., 230) depicting a two-dimensional representation (e.g., 233) of the base shoe part (e.g., 226) to which the attachment shoe part (e.g., 224) will be attached. The plurality of other geometric coordinates may comprise a part-position coordinate (e.g., 203) and a part-attachment coordinate (e.g., 201). Step 820 transfers, by the part-transfer apparatus, the attachment shoe part (e.g., 224) to the part-position coordinate (e.g., 203), and step 822 attaches the attachment shoe part to the base part at the part-attachment coordinate (e.g., 201).

The 2-D recognition system described above may also be used for quality control purposes. For instance, the 2-D recognition system may allow for detection of a mismatched attachment part in a set of matching stacked attachment parts. Further, the 2-D recognition system may also enable quality control of shoe-part positioning to ensure position placement accuracy.

As described above, our technology may comprise, among other things, a method, a system, or a set of instructions stored on one or more computer-readable media. Information stored on the computer-readable media may be used to direct operations of a computing device, and an exemplary computing device 900 is depicted in FIG. 9. Computing device 900 is but one example of a suitable computing system and is not intended to suggest any limitation as to the scope of use or functionality of invention aspects. Neither should the computing system 900 be interpreted as having any dependency or requirement relating to any one or combination of components illustrated. Moreover, aspects of the invention may also be practiced in distributed computing systems where tasks are performed by separate or remote-processing devices that are linked through a communications network.

Computing device 900 has a bus 910 that directly or indirectly couples the following components: memory 912, one or more processors 914, one or more presentation components 916, input/output ports 918, input/output components

920, and an illustrative power supply 922. Bus 910 represents what may be one or more busses (such as an address bus, data bus, or combination thereof). Although the various blocks of FIG. 9 are shown with lines for the sake of clarity, in reality, delineating various components is not so clear, and metaphorically, the lines would more accurately be grey and fuzzy. For example, processors may have memory.

Computing device 900 typically may have a variety of computer-readable media. By way of example, and not limitation, computer-readable media may comprises Random Access Memory (RAM); Read Only Memory (ROM); Electronically Erasable Programmable Read Only Memory (EEPROM); flash memory or other memory technologies; CDROM, digital versatile disks (DVD) or other optical or holographic media; magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, carrier wave or any other medium that can be used to encode desired information and be accessed by computing device 900.

Memory 912 is comprised of tangible computer-storage media in the form of volatile and/or nonvolatile memory. Memory 912 may be removable, nonremovable, or a combination thereof. Exemplary hardware devices are solid-state memory, hard drives, optical-disc drives, etc.

Computing device 900 is depicted to have one or more processors 914 that read data from various entities such as memory 912 or I/O components 920. Exemplary data that is read by a processor may be comprised of computer code or machine-useable instructions, which may be computer-executable instructions such as program modules, being executed by a computer or other machine. Generally, program modules such as routines, programs, objects, components, data structures, etc., refer to code that perform particular tasks or implement particular abstract data types.

Presentation component(s) 916 present data indications to a user or other device. Exemplary presentation components are a display device, speaker, printing component, light-emitting component, etc. I/O ports 918 allow computing device 900 to be logically coupled to other devices including I/O components 920, some of which may be built in.

In the context of shoe manufacturing, a computing device 900 may be used to determine operations of various shoe-manufacturing tools. For example, a computing device may be used to control a part-pickup tool or a conveyor that transfers shoe parts from one location to another. In addition, a computing device may be used to control a part-attachment device that attaches (e.g., welds, adheres, stitches, etc.) one shoe part to another shoe part.

B. Assembling Shoe Parts Using a Multi-Functional Manufacturing Tool

Aspects of the present invention also relate to systems, methods, and apparatus for a manufacturing tool. The manufacturing tool is highly adaptable for use with a variety of materials, a variety of shapes, a variety of part sizes, a variety of manufacturing processes, and a variety of locations within an automated manufacturing system. This high level of adaptability provides a manufacturing tool that is a critical component in an automated manufacturing process. To accomplish this, the manufacturing tool is comprised of a vacuum tool and an ultrasonic welder as a unified manufacturing tool that is able to be manipulated from a single positional member. The manufacturing tool may be used to pick and position a manufacturing part such as a shoe part that is then welded or tacked with the associated ultrasonic welder.

FIG. 10 depicts a top-down view of an exemplary vacuum tool 3100, in accordance with embodiments of the present invention. In various aspects, the vacuum tool 3100 may also be referred to as a vacuum-powered part holder, a manufac-

turing tool, a multi-functional manufacturing tool, a part-pickup tool/apparatus, and/or a part-transfer tool/apparatus; all terms are used interchangeably herein. For example, the vacuum tool **3100** may be useable in an automated (or partially automated) manufacturing process for the movement, positioning, and/or maintaining of one or more parts. The parts manipulated by the vacuum tool **3100** may be rigid, malleable, or any combination of characteristics (e.g., porous, non-porous). In an exemplary aspect, the vacuum tool **3100** is functional for picking and placing a part constructed, at least in part, of leather, polymers, textiles, rubber, foam, mesh, and/or the like.

The material to be manipulated by a vacuum tool may be of any type. For example, it is contemplated that a vacuum tool described herein is adapted for manipulating (e.g., picking and placing) flat, thin, and/or lightweight parts of various shapes, materials, and other physical characteristics (e.g. pattern cut textiles, non-woven materials, mesh, plastic sheeting material, foams, rubber). Therefore, unlike industrial-scaled vacuum tools functional for manipulating a heavy, rigid, or non-porous material, the vacuum tools provided herein are able to effectively manipulate a variety of materials (e.g., light, porous, flexible).

The vacuum tool **3100** is comprised of a vacuum generator **3102**. The vacuum generator generates a vacuum force (e.g., low pressure gradient relative to ambient conditions). For example, the vacuum generator **3102** may utilize traditional vacuum pumps operated by a motor (or engine). The vacuum generator **3102** may also utilize a venturi pump to generate a vacuum. Further yet, it is contemplated that an air amplifier, which is also referred to as a coandă effect pump, is also utilized to generate a vacuum force. Both the venturi pump and the coandă effect pump operate on varied principles of converting a pressurized gas into a vacuum force effective for maintaining a suction action. While the following disclosure will focus on the venturi pump and/or the coandă effect pump, it is contemplated that the vacuum generator **3102** may also be a mechanical vacuum that is either local or remote (coupled by way of tubing, piping, and the like) to the vacuum tool **3100**.

The vacuum tool **3100** of FIG. **1** is also comprised of a vacuum distributor **3110**. The vacuum distributor **3110** distributes a vacuum force generated by the vacuum generator **3102** across a defined surface area. For example, a material to be manipulated by the vacuum tool **3100** may be a flexible material of several square inches in surface area (e.g., a leather portion for a shoe upper). As a result of the material being at least semi-flexible, the vacuum force used to pick up the part may be advantageously dispersed across a substantial area of the part. For example, rather than focusing a suction effect on a limited surface area of a flexible part, which may result in bending or creasing of the part once support underneath of the part is removed (e.g., when the part is lifted), dispersing the suction effect across a greater area may inhibit an undesired bending or creasing of the part. Further, it is contemplated that a concentrated vacuum (non-dispersed vacuum force) may damage a part once a sufficient vacuum is applied. Therefore, in an aspect of the present invention, the vacuum force generated by the vacuum generator **3102** is distributed across a larger potential surface area by way of the vacuum distributor **3110**.

In an exemplary aspect, the vacuum distributor **3110** is formed from a semi-rigid to rigid material, such as metal (e.g., aluminum) or polymers. However, other materials are contemplated. The vacuum tool **3100** is contemplated as being manipulated (e.g. moved/positioned) by a robot, such as a multi-axis programmable robot in response to instructions

received from, for example, a part-recognition system. As such, limitations of a robot may be taken into consideration for the vacuum tool **3100**. For example, weight of the vacuum tool **3100** (and/or a manufacturing tool **3310** to be discussed hereinafter) may be desired to be limited in order to limit the potential size and/or costs associated with a manipulating robot. Utilizing weight as a limiting factor, it may be advantageous to form the vacuum distributor in a particular manner to reduce weight while still achieving a desired distribution of the vacuum force.

Other consideration may be evaluated in the design and implementation of the vacuum tool **3100**. For example, a desired level of rigidity of the vacuum tool **3100** may result in reinforcement portions and material-removed portions, as will be discussed with respect to FIG. **26** hereinafter, being incorporated into the vacuum tool **3100**.

The vacuum distributor **3110** is comprised of an exterior top surface **3112** and an exterior side surface **3116**. FIG. **10** depicts a vacuum distributor with a substantially rectangular footprint. However, it is contemplated that any footprint may be utilized. For example, a non-circular footprint may be utilized. A non-circular footprint, in an exemplary aspect, may be advantageous as providing a larger useable surface area for manipulating a variety of part geometries. Therefore, the use of a non-circular footprint may allow for a greater percentage of the footprint to be in contact with a manipulated part as compared to a circular footprint. Also with respect to shape of a vacuum tool **3100** beyond the footprint, it is contemplated, as will be discussed hereinafter, that any three-dimensional geometry may be implemented for the vacuum distributor **3110**. For example, an egg-like geometry, a pyramid-like geometry, a cubical-like geometry, and the like may be utilized.

The exemplary vacuum distributor **3110** of FIG. **10** is comprised of the exterior top surface **3112** and a plurality of exterior side surfaces **3116**. The vacuum distributor **3110** also terminates at edges resulting in a first side edge **3128**, a second parallel side edge **3130**, a front edge **3132**, and an opposite parallel back edge **3134**.

FIG. **10** depicts a cutline **12-12** demarking a parallel view perspective for FIG. **11**. FIG. **11** depicts a front-to-back perspective cut view that is parallel along cut line **12-12** of the vacuum tool **3100**, in accordance with aspects of the present invention. FIG. **11** depicts, among other features, a vacuum distribution cavity **3140** and a vacuum plate **3150** (also sometimes referred to as the "plate" herein). The vacuum distributor **3110** and the plate **3150**, in combination, define a volume of space forming the vacuum distribution cavity **3140**. The vacuum distribution cavity **3140** is a volume of space that allows for the unobstructed flow of gas to allow for an equalized dispersion of a vacuum force. In an exemplary aspect, the flow of gas (e.g., air) from the plate **3150** to the vacuum generator **3102** is focused through the utilization of angled interior side surface(s) **3118**. As depicted in FIG. **11**, there are four primary interior side surfaces, a first interior side surface **3120** (not shown), a second interior side surface **3122**, a third interior side surface **3124**, and a fourth interior side surface **3126** (not shown). However, it is contemplated that other geometries may be utilized.

The interior side surfaces **3118** extend from the interior top surface **3114** toward the plate **3150**. In an exemplary aspect, an obtuse angle **3142** is formed between the interior top surface and the interior side surfaces **3118**. The obtuse angle **3142** provides an air vacuum distribution effect that reduces internal turbulence of air as it passes from the plate **3150** toward a vacuum aperture **3138** serving the vacuum generator **3102**. By angling the approach of air as it enters the vacuum

aperture **3138**, a reduced amount of material may be utilized with the vacuum distributor **3110** (e.g., resulting in a potential reduction in weight) and the flow of air may be controlled through a reduction in air turbulence. An angle **3144** may also be defined by the intersection of the interior side surfaces **3118** and the plate **3150**.

The plate **3150**, which will be discussed in greater detail in FIGS. **15-24** hereinafter, has an interior plate surface **3152** (i.e., top surface) and an opposite exterior plate surface **3158** (i.e., bottom surface). The exterior plate surface **3158** is adapted for contacting a part to be manipulated by the vacuum tool **3100**. For example, the plate **3150** in general, or the exterior plate surface **3158** in particular, may be formed from a non-marring material. For example, aluminum or a polymer may be used to form the plate **3150** in whole or in part. Further, it is contemplated that the plate **3150** is a semi-rigid or rigid structure to resist forces exerted on it from the vacuum generated by the vacuum generator **3102**. Therefore, the plate **3150** may be formed of a material having a sufficient thickness to resist deforming under pressures created by the vacuum generator **3102**. Additionally, it is contemplated that the plate **3150** is formed from a material that conforms, in part, to an item to be manipulated. For example, the plate **3150** may be constructed from a mesh-like material having a plurality of apertures defined by voids in the mesh-like material (e.g., textile mesh, metal mesh).

When used in combination, the vacuum generator **3102**, the vacuum distributor **3110**, and the plate **3150**, the vacuum tool **3100** is functional to generate a suction force that draws a material towards the exterior plate surface **3158** (also referred to as a manufacturing-part-contacting surface) where the material is maintained against the plate **3150** until the force applied to the material is less than a force repelling (e.g., gravity, vacuum) the material from the plate **3150**. In use, the vacuum tool **3100** is therefore able to approach a part, generate a vacuum force capable of temporarily maintaining the part in contact with the plate **3150**, move the vacuum tool **3100** and the part to a new location, and then allow the part to release from the vacuum tool **3100** at the new position (e.g., at a new location, in contact with a new material, at a new manufacturing process, and the like).

FIG. **12** depicts a front-to-back view of the vacuum tool **3100** along the cutline **12-12** of FIG. **10**, in accordance with aspects of the present invention. In particular, FIG. **12** provides a cut view of the vacuum generator **3102**. As will be discussed in greater detail with respect to FIG. **13**, the vacuum generator **3102**, in the exemplary aspect, is an air amplifier utilizing a coandă effect to generate a vacuum force.

In this example, air is drawn from the exterior plate surface **3158** through a plurality of apertures **3160** through the plate **3150** to the vacuum distribution cavity **3140**. The vacuum distribution cavity **3140** is enclosed between the vacuum distributor **3110** and the plate **3150**, such that if the plate **3150** is a non-porous (i.e., lacked the plurality of apertures **3160**) surface, then an area of low pressure would be generated in the vacuum distribution cavity **3140** when the vacuum generator **3102** is activated. However, returning to the example including the plurality of apertures **3160**, the air is drawn into the vacuum distribution cavity **3140** towards the vacuum aperture **3138**, which then allows the air to be drawn into the vacuum generator **3102**.

FIG. **13** identifies a zoomed view of the vacuum generator **3102** depicted in FIG. **12**. FIG. **13** depicts a focused view of the vacuum generator **3102** as cut along the cutline **12-12** from FIG. **10**, in accordance with aspects of the present invention. The vacuum generator depicted in FIG. **13** is a coandă effect (i.e., air amplifier) vacuum pump **3106**. The coandă

effect vacuum pump injects pressurized air at an inlet **3103**. The inlet **3103** directs the pressurized air through an internal chamber **3302** to a sidewall flange **3304**. The pressurized air, utilizing the coandă effect, curves around the sidewall flange **3304** and flows along an internal sidewall **3306**. As a result of the pressurized air movement, a vacuum force is generated in the same direction as the flow of the pressurized air along the internal sidewall **3306**. Consequently, a direction of suction extends up through the vacuum aperture **3138**.

FIG. **14** depicts an exemplary plate **3150** comprised of the plurality of apertures **3160**, in accordance with aspects of the present invention. While the plate **3150** is illustrated as having a rectangular footprint, as previously discussed, it is contemplated that any geometry may be implemented (e.g., circular, non-circular) depending, in part, on the material to be manipulated, a robot or positional member controlling the vacuum tool **3100**, and/or components of the vacuum tool **3100**.

The plurality of apertures **3160** may be defined, at least in part, by a geometry (e.g., circular, hatch, bulbous, rectangular), size (e.g., diameter, radius (e.g., radius **3167**), area, length, width), offset (e.g., offset **3169**) from elements (e.g., distance from outer edge, distance from a non-porous portion), and pitch (e.g., distance between apertures (e.g., pitch **3168**)). The pitch of two apertures is defined as a distance from a first aperture (e.g., first aperture **3162**) to a second aperture (e.g., second aperture **3164**). The pitch may be measured in a variety of manners. For example, the pitch may be measured from the closest two points of two apertures, from the surface area center of two apertures (e.g., centre of circular apertures), and/or from a particular feature of two apertures.

Depending on desired characteristics of a vacuum tool, the variables associated with the apertures may be adjusted. For example, a non-porous material of low density may not require much vacuum force to maintain the material in contact with the vacuum tool under normal operating conditions. However, a large porous mesh material may, on the other hand, require a significant amount of vacuum force to maintain the material against the vacuum tool under normal operating conditions. Therefore, to limit the amount of energy placed into the system (e.g., amount of pressurized air to operate a coandă effect vacuum pump, electricity to operate a mechanical vacuum pump) an optimization of the apertures may be implemented.

For example, a variable that may be sufficient for typical materials handled in a footwear, apparel, and the like industry may include, but not be limited to, apertures having a diameter between 0.5 and 5 millimeters (mm), between 1 mm and 4 mm, between 1 mm and 3 mm, 1.5 mm, 2 mm, 2.5 mm, 3 mm, and the like. However, larger and smaller diameter (or comparable surface area) apertures are contemplated. Similarly, the pitch may range between 1 mm and 8 mm, between 2 mm and 6 mm, between 2 mm and 5 mm, 3 mm, 3.5 mm, 4 mm, 4.5 mm, 5 mm, 5.5 mm, 6 mm, and the like. However, larger and smaller pitch measurements are contemplated.

Additionally, it is contemplated that a variable size and a variable pitch may be implemented in aspects of the present invention. For example, a compound part composed of both a porous material portion and a non-porous material portion may utilize different variables to accomplish the same level of manipulation. In this example, variables that lead to a reduction in necessary vacuum force in an area to be contacted by the non-porous material and variables that lead to higher vacuum forces in an area to be contacted by the porous material may be implemented. Further, a vision system or other part-identification system may be used in conjunction to fur-

ther ensure a proper placement of the material with respect to the plurality of apertures. Additionally, it is contemplated that a relationship between pitch and size may be utilized to locate the plurality of apertures. For example, a pitch from a larger-sized aperture may be greater than a pitch from a smaller-sized aperture (or vice versa).

An additional variable is the offset. In an exemplary aspect, the offset is a distance of an aperture from an outside edge of the plate 3150. Different apertures may have different offsets. Further different edges may implement different offsets. For example an offset along a front edge may be different from an offset along a side edge. The offset may range from no offset to 8 mm (or more). In practice, an offset ranging from 1 mm to 5 mm may accomplish characteristics of exemplary aspects of the present invention.

The plurality of apertures 3160 may be formed in the plate 3150 utilizing a number of manufacturing techniques. For example apertures may be punched, drilled, etched, carved, melted, and/or cut from the plate 3150. In an exemplary embodiment, the plate 3150 is formed from a material that is responsive to laser cutting. For example polymer-based materials and some metal-based materials may be used in conjunction with laser cutting of the plurality of apertures.

FIGS. 15-24 provide exemplary aperture variable selections similar to that discussed with respect to FIG. 14, in accordance with aspects of the present invention. The following examples are not intended to be limiting, but instead exemplary in nature. FIG. 15 depicts non-circular apertures having a first offset of 5 mm and a second offset of 8 mm and a pitch of 7 mm. FIG. 16 depicts circular apertures having an offset and pitch of 5 mm with a diameter of 2 mm. FIG. 17 depicts circular apertures having a diameter of 1 mm, a pitch of 2 mm, and offsets of 4 mm and 5 mm. FIG. 18 depicts circular apertures having a diameter of 2 mm, a pitch of 4 mm, and offsets of 5 mm and 4 mm. FIG. 19 depicts exemplary geometric apertures having a pitch of 4 mm and offsets of 5 mm. FIG. 20 depicts circular apertures having a diameter of 1 mm, a pitch of 4 mm, and offsets of 5 mm and 4 mm. FIG. 21 depicts circular apertures having a diameter of 1 mm, a pitch of 5 mm, and offsets of 5 mm. FIG. 22 depicts circular apertures having a diameter of 1.5 mm, a pitch of 4 mm, and offsets of 5 mm and 4 mm. FIG. 23 depicts circular apertures having a diameter of 1.5 mm, a pitch of 3 mm, and offsets of 4 mm. FIG. 24 depicts circular apertures having a diameter of 2 mm, a pitch of 3 mm, and offsets of 5 mm and 4 mm. As previously discussed, it is contemplated that shape, size, pitch, and offset may be altered uniformly or variably in any combination to achieve a desired result.

FIG. 25 depicts an exploded view of a manufacturing tool 3310 comprised of a vacuum tool 3100 and an ultrasonic welder 3200, in accordance with aspects of the present invention. Unlike the vacuum tool 3100 discussed with respect to FIGS. 10 and 11, the vacuum tool 3100 of FIG. 25 incorporates a plurality of vacuum generators 3102, vacuum distributors 3110, and vacuum distribution cavities 3140 into a unified vacuum tool 3100. As will be discussed hereinafter, advantages may be realized by the ability to selectively activate/deactivate vacuum force in individual portions of the vacuum tool 3100. Additionally, a greater control of continuous vacuum force may be achieved by having segregated portions of the vacuum tool 3100.

The manufacturing tool 3310 also is comprised of a coupling member 3300. The coupling member 3300 is a feature of the manufacturing tool 3310 (or the vacuum tool 3100 or the ultrasonic welder 3200 individually) allowing a positional member (not shown) to manipulate the position, attitude, and/or orientation of the manufacturing tool 3310. For example, the coupling member 3300 may allow for the addition of the manufacturing tool to a computer-numerically-controlled (CNC) robot that has a series of instructions embodied on a non-transitory computer-readable medium, that when executed by a processor and memory, cause the CNC robot to perform a series of steps. For example, the CNC robot may control the vacuum generator(s) 3102, the ultrasonic welder 3200, and/or the position to which the manufacturing tool 3310 is located in response to instructions received from a part-recognition system. The coupling member 3300 may, therefore, allow for the temporary or permanent coupling of the manufacturing tool 3310 to a positional member, such as a CNC robot.

As was previously discussed, aspects of the present invention may form portions of the manufacturing tool 3310 with the intention of minimizing mass. As such, the plurality of vacuum distributors 3110 of FIG. 25 include reduced material portions 3113. The reduced material portions 3113 eliminate portions of what could otherwise be a uniform exterior top surface. The introduction of reduced material portions 3113 reduces weight of the manufacturing tool 3310 to allow for a potentially smaller positional member to be utilized, which may save on space and costs. Additional locations for reduced material portions 3113 are contemplated about the vacuum tool 3100 (e.g., side, bottom, top).

However, aspects of the present invention may desire to remain a level of rigidity of the plurality of vacuum distributors 3110 as supported by a single coupling member 3300. To maintain a level of rigidity while still introducing the reduced material portions 3113, reinforcement portions 3115 may also be introduced. For example, reinforcement portions 3115 may extend from one vacuum distributor 3110 to another vacuum distributor 3110. Further yet, it is contemplated that in aspects of the present invention, reinforcement portions 3115 may be included proximate to the coupling member 3300 for a similar rationale.

The plate 3150 is separated from the plurality of vacuum distributors 3110 in FIG. 25 for illustrative purposes. As a result, an interior plate surface 3152 is viewable. Traditionally, the interior plate surface 3152 is mated with a bottom portion of the plurality of vacuum distributors 3110, forming an air-tight bond.

The vacuum tool 3100 is comprised of a plurality of vacuum generators 3102, vacuum distributors 3110, and associated vacuum distribution cavities 3140. It is contemplated that any number of each may be utilized in a vacuum tool 3100. For example, it is contemplated that 10, 8, 6, 4, 2, 1, or any number of units may be combined to form a cohesive vacuum tool 3100. Further, any footprint may be formed. For example, while a rectangular footprint is depicted in FIG. 25, it is contemplated that a square, triangular, circular, non-circular, part-matching shape, or the like may instead be implemented (e.g., the units may be modular such that depending on the material to be manipulated additional units may be added or removed from the vacuum tool 3100. A coupling mechanism may couple a first vacuum distributor 3110 with one or more additional vacuum distributors 3110 to form the vacuum tool 3100). Additionally, the size of the vacuum generator 3102 and/or the vacuum distributor 3110 may be varied (e.g., non-uniform) in various aspects. For example, in an exemplary aspect, where a greater concentration of vacuum force is needed for a particular application, a smaller vacuum distributor may be utilized, and where a less concentrated vacuum force is needed, a larger vacuum distributor may be implemented.

FIGS. 25-34 depict exemplary manufacturing tools 3310; however, it is understood that one or more components may

be added or removed from each aspect. For example, each aspect is comprised of an ultrasonic welder **3200** and a vacuum tool **3100**, but it is contemplated that the ultrasonic welder **3200** may be eliminated all together. Similarly, it is contemplated that one or more additional ultrasonic welders **3200** may be implemented in conjunction with the various aspects. Further, it is contemplated that additional features may also be incorporated. For example, part-recognition systems, adhesive applicators (e.g., spray, roll, hot-melt, and other application methods), mechanical fastening components, pressure applicators, curing devices (e.g., ultraviolet light, infrared light, heat applicators, and chemical applicators), lasers, heat welders, arc welders, microwaves, other energy concentrating fastening devices, and the like may also be incorporated in whole or in part in exemplary aspects. For example, any of the above-referenced fastening tools (e.g., adhesive applicators, mechanical fasteners, welders, and the like) may be used in addition to or instead of an ultrasonic welder as discussed herein. Therefore, aspects contemplate alternative fastening tools used in conjunction with one or more vacuum tools.

The ultrasonic welder **3200**, in an exemplary aspect, is comprised of a stack comprised of an ultrasonic welding horn **3210** (may also be referred to as a sonotrode), a converter **3220** (may also be referred to as a piezoelectric transducer), and a booster (not labeled). The ultrasonic welder **3200** may further be comprised of an electronic ultrasonic generator (may also be referred to as a power supply) and a controller. The electronic ultrasonic generator may be useable for delivering a high-powered alternating current signal with a frequency matching the resonance frequency of the stack (e.g., horn, converter, and booster). The controller controls the delivery of the ultrasonic energy from the ultrasonic welder to one or more parts.

Within the stack, the converter converts the electrical signal received from the electronic ultrasonic generator into a mechanical vibration. The booster modifies the amplitude of the vibration from the converter. The ultrasonic welding horn applies the mechanical vibration to the one or more parts to be welded in order to attach the one or more parts. The attachment may be temporary or permanent. For example, temporary attachment may be utilized to hold parts in place in anticipation of additional parts being added and/or attached. The ultrasonic welding horn is comprised of a distal end **3212** adapted for contacting a part. For example, the distal end **3212** may be formed so as to effectively transmit the mechanical vibration to the part while limiting the necessary time, pressure, and/or surface area necessary for a particular weld. For example, the distal end may be adapted to result in a welding head spot size of a particular size for the materials to be welded. The ultrasonic welding head spot size may be in a diameter range from 1 mm to 8 mm, or in particular at/about 4 mm, 4.5 mm, 5 mm, 5.5 mm, 6 mm, and/or 6.5 mm in diameter. Further, a variety ultrasonic welding frequencies may be implemented, such as 15 kHz to 70 kHz. In an exemplary aspect, the welding frequency may be 15 kHz to 35 kHz, 25 kHz to 30 kHz, 26 kHz, 27 kHz, 28 kHz, and/or 29 kHz. Various other power utilization variables may be altered. For example, power consumption may also include wattage of the ultrasonic welder. The wattage may be adjusted based on the material, time, pressure, thickness, weld penetration, etc. In an exemplary aspect, the wattage may be about 300 watts.

The ultrasonic welder **3200** may be positioned at a plurality of locations relative to the vacuum tool **3100**. For example, the ultrasonic welder may be located at any location along the perimeter of the vacuum tool **3100**. Further, it is contemplated that the ultrasonic welder **3200** is offset from the perimeter of

the vacuum tool **3100** at any distance. In an exemplary aspect, the ultrasonic welder **3200** is located along the perimeter proximate the coupling member **3300** to minimize movement of the manufacturing tool **3310** when transitioning from vacuum to welding. Further, it is contemplated that a plurality of ultrasonic welders **3200** are utilized at a variety of locations about the vacuum tool **3100** to further reduce travel time of the manufacturing tool **3310**. Further yet, it is contemplated that one or more ultrasonic welding tools are integrated into the vacuum tool **3100**. For example, an ultrasonic welder may be integrated at a location between two discrete vacuum distributors (e.g., location of reduced material portions **3113**); such that an ultrasonic welder **3200** may extend from a top surface of the vacuum tool **3100** through to the exterior plate surface **3158**. Therefore, it is contemplated that any fastening tool (such as an ultrasonic welder) may extend through the top surface of the vacuum tool through the exterior plate **3158** at any location and at any orientation relative to the vacuum tool. As will be discussed in further detail with respect to FIG. **34**, a biasing mechanism may also be implemented to allow portions of the vacuum tool **3100** to apply a greater compressive force than utilized by the ultrasonic welder **3200** (e.g., to provide stabilization of the parts to be welded).

FIG. **26** depicts a top-down view of the manufacturing tool **3310** previously depicted in FIG. **25**, in accordance with aspects of the present invention. The top perspective of FIG. **26** provides an exemplary view of a potential orientation of a plurality of vacuum distributors **3110** to form a vacuum tool **3100**. As will be discussed hereinafter with respect to FIG. **29**, various vacuum generator **3102**/vacuum distributor **3110** combinations may be selectively activated and/or deactivated to manipulate particular parts.

FIG. **27** depicts a side-perspective view of the manufacturing tool **3310** previously depicted in FIG. **25**, in accordance with aspects of the present invention. The distal end **3212** of the horn **3210** extends below a plane defined by the exterior plate surface **3158**. As a result of the distal end **3212** extending beyond the plane, the distal end **3212** may contact material without interference from the vacuum tool **3100** portion of the manufacturing tool **3310**. However, it is contemplated that the distal end **3212** extends approximately even with the exterior plate surface **3158** plane. Further, it is contemplated that the distal end **3212** does not extend through the plane defined by the exterior plate surface **3158** plane. In this example, it is contemplated that the vacuum tool **3100** is moveably coupled to the coupling member allowing the exterior plate surface **3158** plane to move relative to the distal end **3212** (e.g., biasing mechanism, such as springs and/or pneumatics, may allow the exterior plate surface **3158** plane to move upwards once a sufficient pressure is applied to the exterior plate surface **3158**). Further yet, it is contemplated that the distal end **3212** (and/or the ultrasonic welder **3200** in general) is oriented on the manufacturing tool **3310** such that a rotation about an axis by the positional member alters a material manipulating plane from that defined by the exterior plate surface **3158** plane to a plane defined by the distal end **3212** (e.g., the vacuum tool **3100** is rotated from being parallel to the materials being manipulated until the ultrasonic welder **3200** is perpendicular (or any acceptable angle) to the material to be welded). Stated differently, it is contemplated that instead of positioning the distal end **3212** in an appropriate location utilizing X-Y-Z movements, a rotation about an X-axis, Y-axis, and/or Z-axis may be implemented to position the distal end **3212**.

FIG. **28** depicts an exploded-perspective view of a manufacturing tool **3310** comprised of six discrete vacuum distributors **3110**, in accordance with aspects of the present

invention. The plate **3150** is depicted in this exemplary aspect as having a plurality of apertures **3160** and non-aperture portions **3170**. The non-aperture portion **3170** is a portion of the plate **3150** through which apertures do not extend. For example, along a segment where two vacuum distributors **3110** converge the plate **3150** may include a non-aperture portion **3170** to prevent cross feeding of vacuum between two associated vacuum distribution cavities **3140**. Further, it is contemplated that non-aperture portion **3170** may extend along a segment in which the plate **3150** is bonded (temporarily or permanently) to one or more portions of the vacuum distributor(s) **3110**. Further yet, it is contemplated that one or more non-aperture portions are integrated into the plate **3150** to further control the placement of vacuum forces as dispersed along the exterior plate surface **3158**. Additionally, the non-aperture portion **3170** may be implemented in an area intended to be in contact with malleable (and other characteristics) portions of material that may not react well to the application of vacuum as transferred by one or more apertures.

FIG. **29** depicts a top-down perspective of the manufacturing tool **3310** previously discussed with respect to FIG. **28**, in accordance with exemplary aspects of the present invention. In particular six discrete vacuum tool portions are identified as a first vacuum portion **3402**, a second vacuum portion **3404**, a third vacuum portion **3406**, a fourth vacuum portion **3408**, a fifth vacuum portion **3410**, and a fifth vacuum portion **3412**. In an exemplary aspect of the present invention, one or more vacuum portions may be selectively activated and deactivated. It is understood that this functionality may be applied to all aspects provided herein, but are only discussed with respect to the present FIG. **29** for brevity reasons.

FIG. **30** depicts a side perspective of the manufacturing tool **3310** of FIG. **28**, in accordance with aspects of the present invention.

FIG. **31** depicts a manufacturing tool **3310** comprised of a vacuum tool **3100** and an ultrasonic welder **3200**, in accordance with aspects of the present invention. In particular, the vacuum tool **3100** of FIG. **31** is a venturi vacuum generator **3104**. A venturi vacuum generator, similar to a coandă effect vacuum pump, utilizes pressurized air to generate a vacuum force. The vacuum tool **3100** of FIG. **31** differs from the vacuum tool **3100** of the previously discussed figures in that the vacuum tool **3100** of FIG. **31** utilizes a single aperture as opposed to a plate having a plurality of apertures. In an exemplary aspect, the concentration of vacuum force to a single aperture may allow for higher degree of concentrated part manipulation. For example, small parts that may not require even a whole single portion of a multi-portion vacuum tool to be activated may benefit from manipulation by the single aperture vacuum tool of FIG. **31**. However, additional aspects contemplate utilizing a plate having a plurality of apertures that are not intended for contacting/covered-by a to-be manipulated part (e.g., resulting in a loss of suction that may traditionally be undesirable).

The single aperture vacuum tool of FIG. **31** utilizes a cup **3161** for transferring the vacuum force from the venturi vacuum generator **3104** to a manipulated part. The cup **3161** has a bottom surface **3159** that is adapted for contacting a part. For example, a surface finish, surface material, or size of the bottom surface may be suitable for contacting a part to be manipulated. The bottom surface **3159** may define a plane similar to the plane previously discussed as being defined from the exterior plate surface **3158** of FIG. **27**, for example. As such, it is contemplated that the distal end **3212** of the ultrasonic welder **3200** may be defined relative to the plane of the bottom surface **3159**.

It is contemplated that the cup **3161** may be adjusted based on a part to be manipulated. For example, if a part has a certain shape, porosity, density, and/or material, then a different cup **3161** may be utilized.

While two combinations of vacuum tool **3100** and ultrasonic welder **3200** are depicted as forming the manufacturing tool **3310** of FIG. **31**, it is contemplated that any number of features may be implemented. For example, a plurality of vacuum tools **3100** may be utilized in conjunction with a single ultrasonic welder **3200**. Similarly, it is contemplated that a plurality of ultrasonic welders **3200** may be implemented in conjunction with a single vacuum tool **3100**. Further, it is contemplated that various types of vacuum tools may be implemented in conjunction. For example, a manufacturing tool **3310** may be comprised of a single aperture vacuum tool and a multi-aperture vacuum tool (e.g., FIG. **31**). Further yet, it is contemplated that one or more single aperture vacuum tools are coupled with one or more multi-aperture vacuum tools and one or more fastening tools. As such, any number of features (e.g., tools) may be combined.

FIG. **32** depicts a top-down perspective of the manufacturing tool of FIG. **31**, in accordance with aspects of the present invention.

FIG. **33** depicts a side perspective of the manufacturing tool of FIG. **31**, in accordance with aspects of the present invention. An offset distance **3169** may be adjusted for the manufacturing tool **3310**. The offset distance **3169** is a distance between the distal end **3212** of the ultrasonic welder **3200** and the cup **3161**. In an exemplary aspect, the distance **3169** is minimized to reduce manufacturing tool **3310** travels from placing a part to welding the part. However, in another exemplary aspect, the distance **3169** is maintained sufficient distance to prevent interference in the manipulation or welding operations by the other tool portion.

FIG. **34** depicts a cut side perspective view of a manufacturing tool **3310** comprised of a single aperture **3160** and an ultrasonic welder **3200**, in accordance with aspects of the present invention. The manufacturing tool **3310** of FIG. **34** incorporates a moveable coupling mechanism by which the ultrasonic welder **3200** is allowed to slide in a direction perpendicular to a plane defined by the bottom surface **3159**. To accomplish this exemplary moveable coupling, a biasing mechanism **3240** is implemented to regulate an amount of pressure the distal end **3212** exerts on a part, regardless of pressure being exerted in the same direction by way of the coupling member **3300**. In this example a flange **3214** slides in a channel that is opposed by the biasing mechanism **3240**. While a spring-type portion is illustrated as the biasing mechanism **3240**, it is contemplated that any mechanism may be implemented (e.g., gravity, counter weight, pneumatic, hydraulic, compressive, tensile, springs, and the like).

In use, it is contemplated that a force may be exerted onto a part by the manufacturing tool **3310** that is greater than necessary for the welding of the part by the ultrasonic welder **3200**. As a result, the greater force may be effective for maintaining a part during a welding operation, while the biasing mechanism **3240** may be used to apply an appropriate pressure force for a current welding operation. Further, it is contemplated that the biasing mechanism may also be used as a dampening mechanism to reduce impact forces experienced by one or more portions of the manufacturing tool **3310** when contacting objects (e.g., parts, work surface).

In use, it is contemplated that a force may be exerted onto a part by the manufacturing tool **3310** that is greater than necessary for the welding of the part by the ultrasonic welder **3200**. As a result, the greater force may be effective for maintaining a part during a welding operation, while the

biasing mechanism **3240** may be used to apply an appropriate pressure force for a current welding operation. For example, it is contemplated that the biasing mechanism **3240** may allow for movement of the distal end **3212** over a range of distances. For example, the range may include 1 mm to 10 mm, 3-6 mm, and/or about 5 mm. Further, it is contemplated that the biasing mechanism may also be used as a dampening mechanism to reduce impact forces experienced by one or more portions of the manufacturing tool **3310** when contacting objects (e.g., parts, work surface).

Further yet, it is contemplated that instead of (or in addition to) utilizing a biasing mechanism, an amount of force exerted by an ultrasonic welder **3200** (or any fastening device) may be adjusted based on the material to be bonded. For example, a determined percentage of compression may be allowed for the materials to be bonded such that an offset height of the distal end from the plate bottom surface may be adjusted to allow for the determined level of compression for particular materials. In practice, highly compressible material may allow for a greater distance between a distal end of the fastening tool and the bottom surface of the vacuum plate as compared to non-highly compressible materials that would not allow for the same amount of compression (measured by size or force).

Further, it is contemplated that the vacuum tool **3100** is alternatively or additionally implementing a biasing mechanism. For example, in an exemplary aspect of the present invention, the amount of pressure exerted by the vacuum tool **3100** may be desired to be less than a pressure exerted by the distal end **3212** on the part. As a result, a form of biasing mechanism **3240** may be employed to controllably exert pressure on to a part by the vacuum tool **3100**.

An amount of force that may be exerted by a distal end having a biasing mechanism (or not having a biasing mechanism) may range from 350 grams to 2500 grams. For example, it is contemplated that the amount of force exerted by the distal end on a part may increase as an amount of distance traveled by a biasing mechanism increases. Therefore, a relationship (e.g., based on a coefficient of the biasing mechanism) may dictate an amount of pressure applied based on a distance traveled. In an exemplary operation, such as affixing a base material, a mesh material, and a skin during a welding operation, about 660 grams of force may be exerted. However, it is contemplated that more or less force may be utilized.

FIG. **35** depicts a method **32600** for joining a plurality of manufacturing parts utilizing a manufacturing tool **3310** comprised of a vacuum tool **3100** and an ultrasonic welder **3200**, in accordance with aspects of the present invention. A block **32602** depicts a step of positioning the manufacturing tool **3310** such that the vacuum tool **3100** is proximate a first part. As used herein, the term proximate may refer to a physical relationship that includes being at, on, and near. For example, the manufacturing tool may be proximate a location when it is within a length or width of the manufacturing tool from the location. Further, it is contemplated that the manufacturing tool is proximate a location when the manufacturing tool is at a location defined to be within tolerance of the part to be manipulated. The positioning of the manufacturing tool **3310** may be accomplished by a positional member, previously discussed. In turn, the positional member may be in communication with a part-recognition system that directs the placement of the manufacturing tool based on image analysis of the first part.

A block **32604** depicts a step of generating a vacuum force transferred through a bottom surface of the vacuum tool **3100**. For example, one or more of the vacuum generators **3102** may

be activated (e.g., as a whole, selectively) to generate a vacuum force that results in a suction effect attracting a part to the exterior plate surface **3158** of FIG. **28** (or the bottom surface **3159** of FIG. **31**). As previously discussed, it is contemplated that one or more vacuum portions may be selectively activated (or deactivated) depending on a desired amount of vacuum force and a desired location of vacuum force.

A block **32606** depicts a step of temporarily maintaining the first part in contact with at least a portion of the vacuum tool **3100**. Therefore, once a vacuum is applied to a part and the part is attracted to the vacuum tool **3100**, the part is maintained in contact with the vacuum tool **3100** so that if the vacuum tool moves (or an underlying supporting surface of the part moves) the part will stay with the vacuum tool. The term temporarily is utilized in this sense so as not to imply a permanent or otherwise significant bond that requires significant effort to separate the part from the vacuum tool. Instead, the part is "temporarily" maintained for the duration that a sufficient vacuum force is applied.

A block **32608** depicts a step of transferring the first part to a second part. The first part may be transferred though a movement of the manufacturing tool **3310**. The movement of the manufacturing tool may be accomplished by a positional member, previously discussed. In turn, the positional member may be in communication with a part-recognition system that directs the transfer of the first part to the second part based on, for example, image analysis of the second part. Further, it is contemplated that the transferring of the first part may be accomplished through the movement of the second part to the first part (e.g., underlying conveyor system brings the second part towards the first part).

A block **32610** depicts a step of releasing the first part from the vacuum tool **3100**. For example, it is contemplated that stopping the generation of vacuum pressure by one or more vacuum generators **3102** is sufficient to effectuate the release of the first part. Further, it is contemplated that a burst of air that is insufficient to generate a vacuum (e.g., insufficient to take advantage of a coandă effect) in the vacuum generator **3102**, but sufficient to cause the release the part may be implemented.

Further, it is contemplated that the releasing of the first part further comprises activating another mechanism that opposes the vacuum pressure of the vacuum tool **3100**. For example, a work surface (e.g., conveyor, table top) opposite of the vacuum tool **3100** may generate a vacuum pressure that counters the vacuum of the vacuum tool. This may allow for precise placement and maintaining of the part as the vacuum tool again transitions to a new position. The countering vacuum pressure may be generated with a mechanical vacuum (e.g., blower) as cycling off and on may not be needed at the same rate as the vacuum tool **3100**.

In an exemplary aspect of the present invention, it is contemplated that a work surface vacuum and a vacuum tool vacuum may have the following on/off relationship for exemplary processes, as depicted in the following tables. While exemplary process are indicated, it is contemplated that additional processes may be substituted or re-arranged within the process. Further, a manufacturing surface, as used herein, reference to a moveable article that may form a base for initially securing, maintaining, aligning, or otherwise assisting in the manufacturing of a product resulting from the manipulated part(s).

Simplified Operations Table

Operation	Work Surface Vacuum	Vacuum Tool Vacuum
Initial State	Off	Off
Manufacturing surface arrives	On	Off
Robot starts to move vacuum tool for part pickup	On	Off
Robot reaches X % distance from part	On	On
Robot begins moving vacuum tool with part to place the part	On	On
Place the part	On	Off
Affixing of part (e.g., welding)	On	Off
End state	On	Off

Additional Operations Table

Operation	Work Surface Vacuum	Vacuum Tool Vacuum
Initial State	Off	Off
Manufacturing surface arrives	On	Off
Robot starts to move vacuum tool for part pickup	On	Off
Robot reaches X % distance from part	On	On
Robot begins moving vacuum tool with part to place the part	On	On
Robot reaches Y % distance from the manufacturing surface	Off	On
Wait Z seconds	Off	On
Place the part	Off	Off
Robot begins moving	Off	Off
Robot positions welder	On	Off
Affixing of part (e.g., welding)	On	Off
End state	On	Off

Consequently, it is contemplated that any combination of work surface vacuum and vacuum tool vacuum may be utilized to accomplish aspects of the present invention. In an exemplary aspect the work surface vacuum is maintained on while a manufacturing surface is present. As a result, the work surface vacuum may utilize a mechanical vacuum generator that may be more efficient, but requires a start up or wind down time than a coanda or a venturi vacuum generator. Further, a mechanical vacuum generator may be able to generate a greater amount of vacuum force over a larger area than the coanda or venturi vacuum generators typically generate.

A block **32612** depicts a step of positioning the manufacturing tool **3310** such that the distal end **3212** of the ultrasonic welder **3200** is proximate the first part. The positioning of the ultrasonic welder may be in response to instructions received from a part-recognition system as outlined above. In this example, it is contemplated that the first part and the second part are intended to be joined utilizing the ultrasonic welder **3200**. Consequently, the ultrasonic welder is positioned in a manner to apply an ultrasonic induced bond between the first part and the second part. The ultrasonic induced bond may be temporary (i.e., for tacking purposes) or permanent.

A block **32614** depicts a step of applying an ultrasonic energy through the horn **3210**. The application of ultrasonic energy bonds the first and the second part with an ultrasonic weld.

While various steps of the method **32600** have been identified, it is contemplated that additional or fewer steps may be implemented. Further, it is contemplated that the steps of method **32600** may be performed in any order and is not limited to the order presented.

Additional arrangements, features, combinations, sub-combination, steps, and the like are contemplated within the provided disclosure. As such, additional embodiments are inherently disclosed by the provided discussion.

What is claimed is:

1. A method for positioning and assembling a shoe part in an automated manner during a shoe-manufacturing process, the method comprising:

receiving an image depicting a two-dimensional representation of an attachment shoe part which is to be attached to a base shoe part;

determining one or more pixel coordinates of the image;

converting, by a computer processor, the one or more pixel coordinates of the image to a geometric coordinate of a geometric coordinate system which maps a three-dimensional space within which the attachment shoe part is positioned and a pick-up tool operates;

determining another geometric coordinate of the geometric coordinate system by analyzing a different image depicting a two-dimensional representation of the base shoe part to which the attachment shoe part will be attached; and

transferring, by the pick-up tool, the attachment shoe part to the other geometric coordinate, thereby moving the attachment shoe part to a location in the three-dimensional space at which the attachment shoe part is to be attached to the base shoe part.

2. The method of claim **1**, wherein the two-dimensional representation of the attachment shoe part is comprised of a two-dimensional shape having a perimeter and wherein the one or more pixel coordinates of the image are associated with the perimeter.

3. The method of claim **1**, further comprising determining the identity of the image by substantially matching the image to a reference image.

4. The method of claim **1**, wherein transferring the attachment shoe part to the other geometric coordinate comprises utilizing a vacuum-powered part holder of the pick-up tool to transfer the attachment shoe part.

5. The method of claim **1**, further comprising attaching the attachment shoe part to the base shoe part.

6. A method of positioning and joining a plurality of shoe parts utilizing automated identification of the shoe parts and a multi-functional manufacturing tool, the method comprising:

receiving an image depicting a two-dimensional representation of an attachment shoe part which is to be attached to a base shoe part;

determining a geometric coordinate of a geometric coordinate system by analyzing the image, wherein the geometric coordinate system maps a three-dimensional space within which the attachment shoe part is positioned and the multi-functional manufacturing tool operates;

determining another geometric coordinate of the geometric coordinate system by analyzing a different image depicting a two-dimensional representation of the base shoe part to which the attachment shoe part will be attached;

transferring, by the a multi-functional manufacturing tool, the attachment shoe part to the other geometric coordinate, thereby moving the attachment shoe part to a location in the three-dimensional space at which the attachment shoe part is to be attached to the base shoe part; and

attaching, by the multi-functional manufacturing tool, the attachment shoe part to the base shoe part.

7. The method of claim **6**, wherein determining the geometric coordinate of the geometric coordinate system by ana-

lyzing the image comprises determining pixel coordinates of the image and converting the pixel coordinates of the image to the geometric coordinate of the geometric coordinate system.

8. The method of claim **7**, wherein transferring the attachment shoe part to the other geometric coordinate comprises utilizing a vacuum-powered part holder of the multi-functional manufacturing tool to transfer the attachment shoe part.

9. The method of claim **6**, wherein attaching the attachment shoe part to the base shoe part comprises utilizing an ultrasonic welding horn of the multi-functional manufacturing tool to attach the attachment shoe part to the base shoe part.

10. A system that positions and attaches a shoe part in an automated manner during a shoe-manufacturing process, the system comprising:

an image recorder that records an image depicting a two-dimensional representation of an attachment shoe part, which is to be attached to a base shoe part; and

computer storage media having stored thereon computer-executable instructions that, when executed, cause a computing device to:

(1) determine pixel coordinates of the image,

(2) convert the pixel coordinates of the image to a geometric coordinate in a geometric coordinate system, which maps a three-dimensional space within which the attachment shoe part is positioned and a manufacturing tool operates,

(3) determine another geometric coordinate in the geometric coordinate system by analyzing a different image of the base shoe part, and

(4) instruct a manufacturing tool to transfer the attachment shoe part to the other geometric coordinate, thereby moving the attachment shoe part to a location in the three-dimensional space at which the attachment shoe part is to be attached to the base shoe part.

11. The system of claim **10** further comprising another image recorder, wherein the different image of the base shoe part is recorded by the other image recorder.

12. The system of claim **10** further comprising a light-emitting device that provides a backlight to the attachment shoe part when the image is recorded.

13. The system of claim **10**, wherein the manufacturing tool comprises at least a vacuum-powered part holder having a bottom surface adapted for contacting the attachment shoe part.

14. The system of claim **13**, wherein the vacuum-powered part holder is comprised of a vacuum plate having a plurality of apertures extending through an interior plate surface and the bottom surface.

15. The system of claim **13**, wherein the vacuum-powered part holder is comprised of a single aperture extending through the bottom surface.

16. The system of claim **13** wherein the manufacturing tool further comprises at least an ultrasonic-welding horn coupled to the vacuum-powered part holder.

17. The system of claim **16**, wherein the ultrasonic-welding horn comprises at least a distal end adapted for contacting the attachment part such that the distal end extends at least to a plane defined by the vacuum-powered part holder bottom surface.

18. The system of claim **17**, wherein only one of the vacuum-powered part holder or the ultrasonic-welding horn are useable for a respective intended purpose at one time.

19. The system of claim **17**, wherein both of the vacuum-powered part holder and the ultrasonic-welding horn are useable for their respective intended purpose at one time.

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